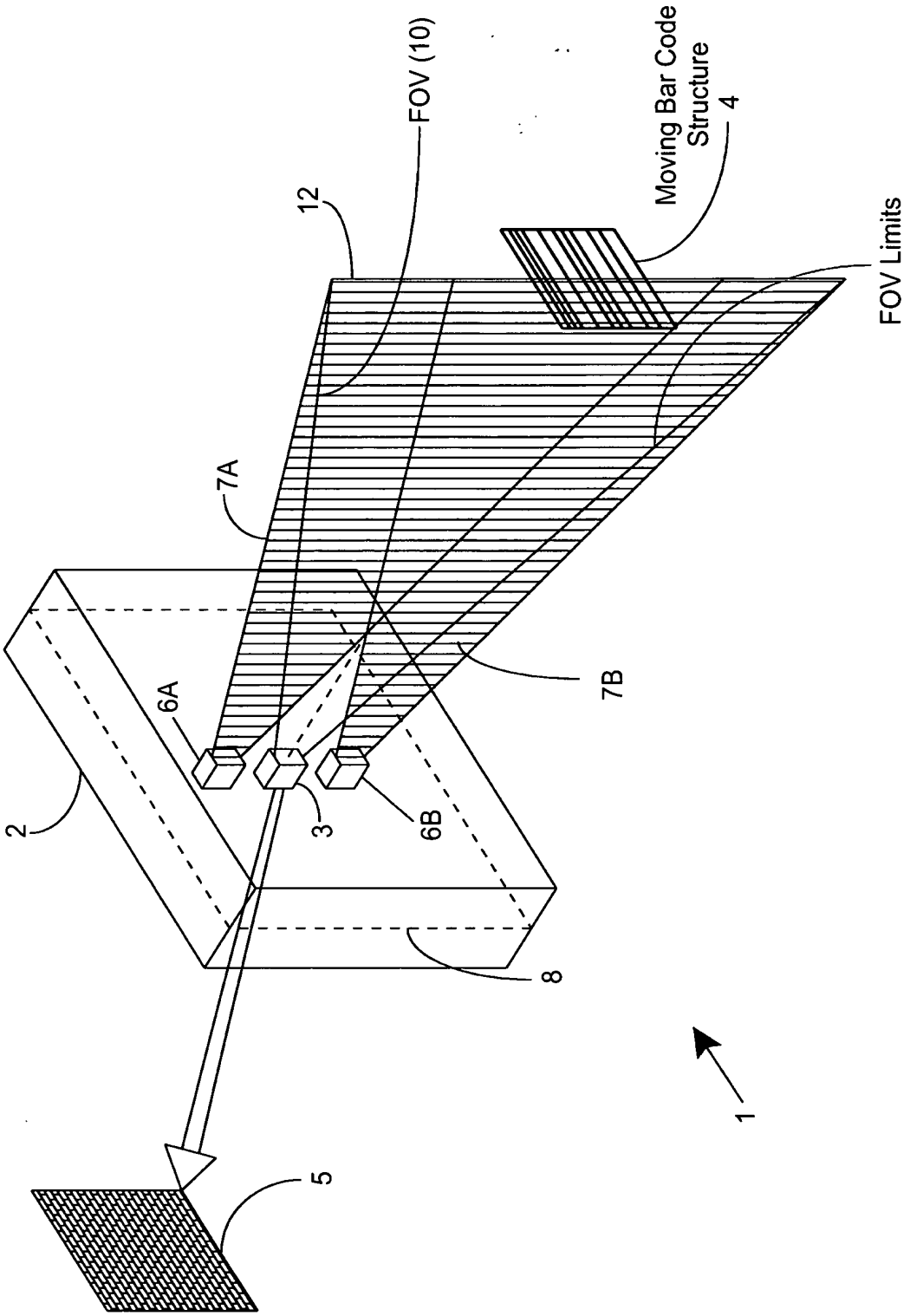


FIG. 1A

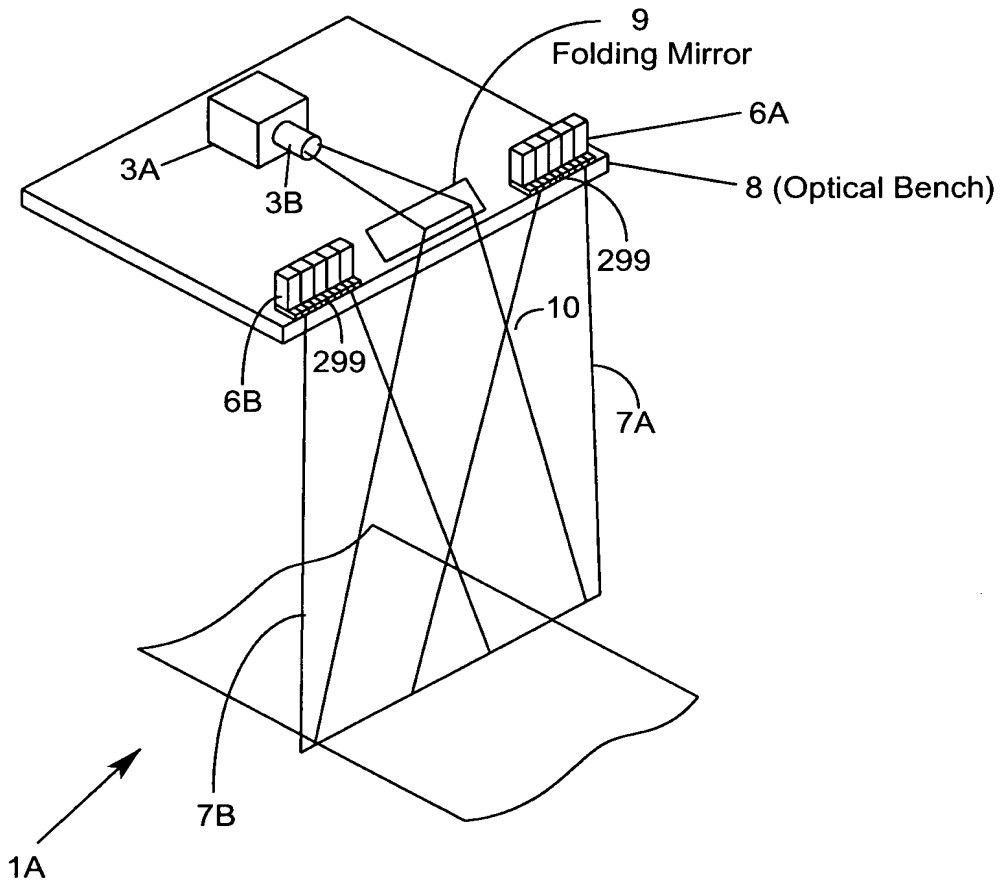


FIG. 1B1

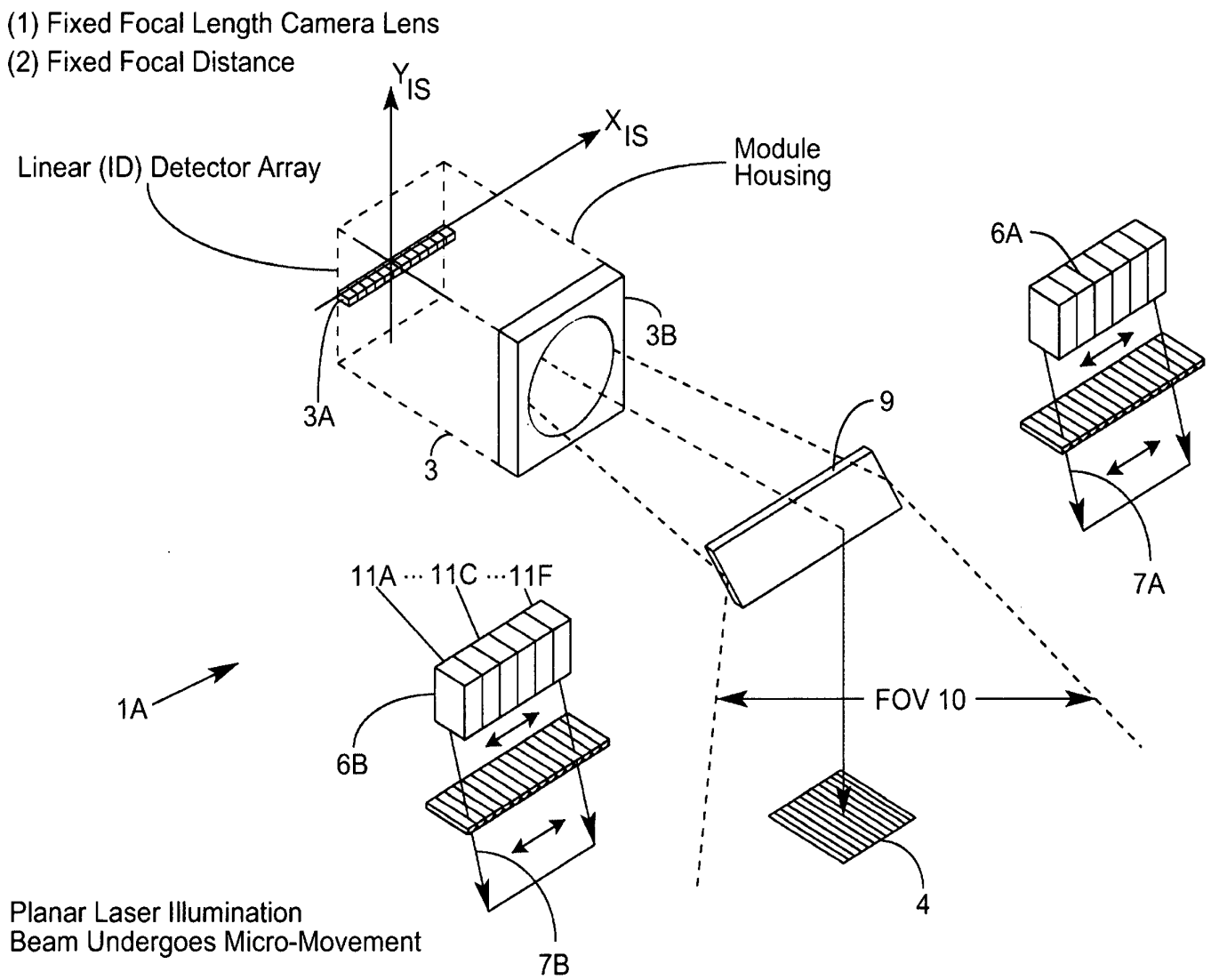

(1) Fixed Focal Length Camera Lens
(2) Fixed Focal Distance
Y_{IS}
X_{IS}
Linear (ID) Detector Array
Module Housing
3B
3A
3
9
6A
7A
11A ··· 11C ···11F
1A
6B
FOV 10
4
7B
Planar Laser Illumination
Beam Undergoes Micro-Movement

FIG. 1B2

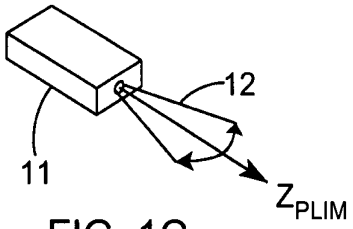


FIG. 1C

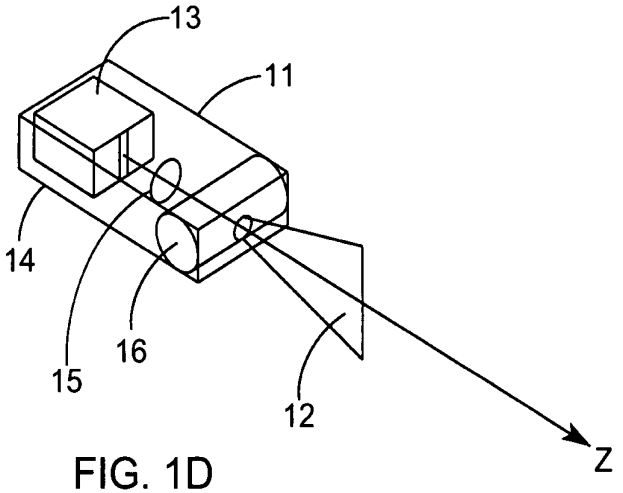


FIG. 1D

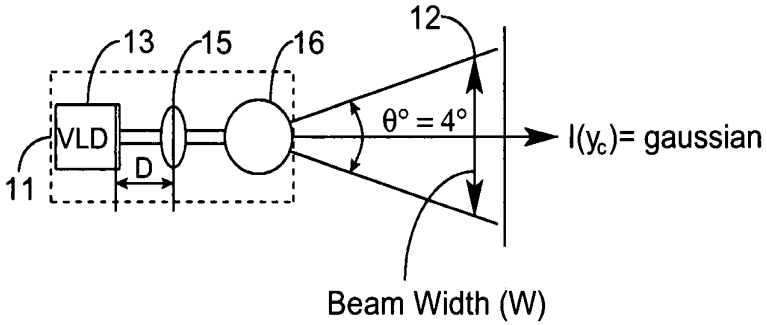


FIG. 1E1

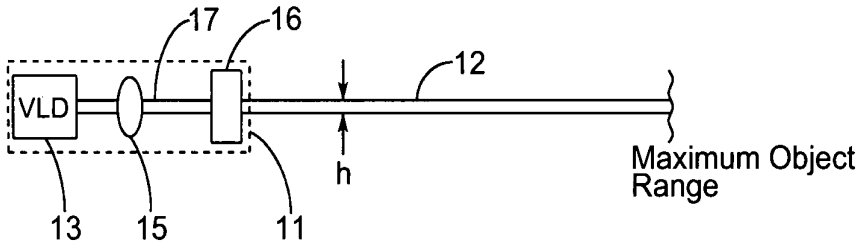


FIG. 1E2

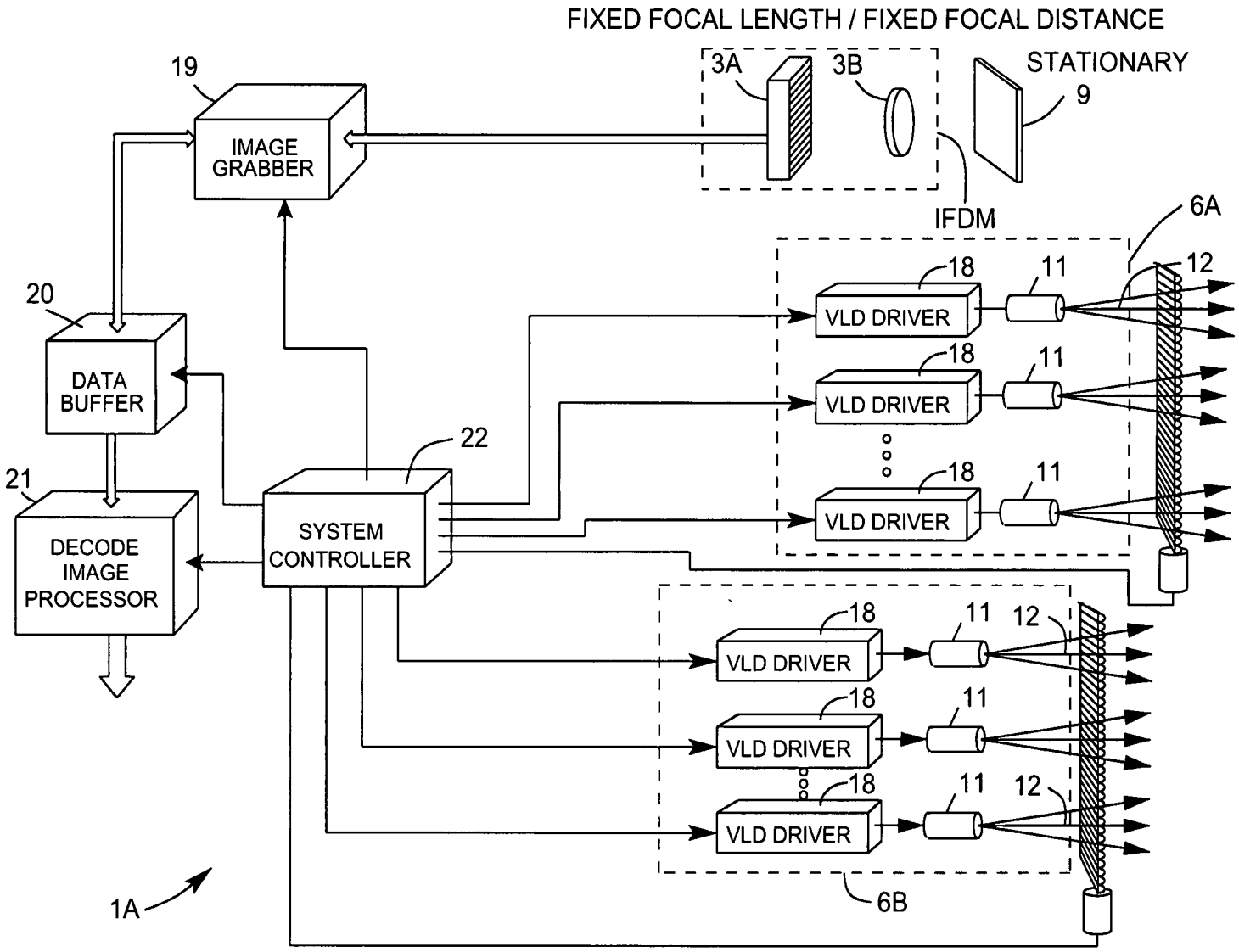

FIXED FOCAL LENGTH / FIXED FOCAL DISTANCE
19
IMAGE GRABBER
3A
3B
STATIONARY
9
IFDM
6A
20
DATA BUFFER
18
11
12
VLD DRIVER
21
DECODE IMAGE PROCESSOR
22
SYSTEM CONTROLLER
6B
1A

FIG. 1F

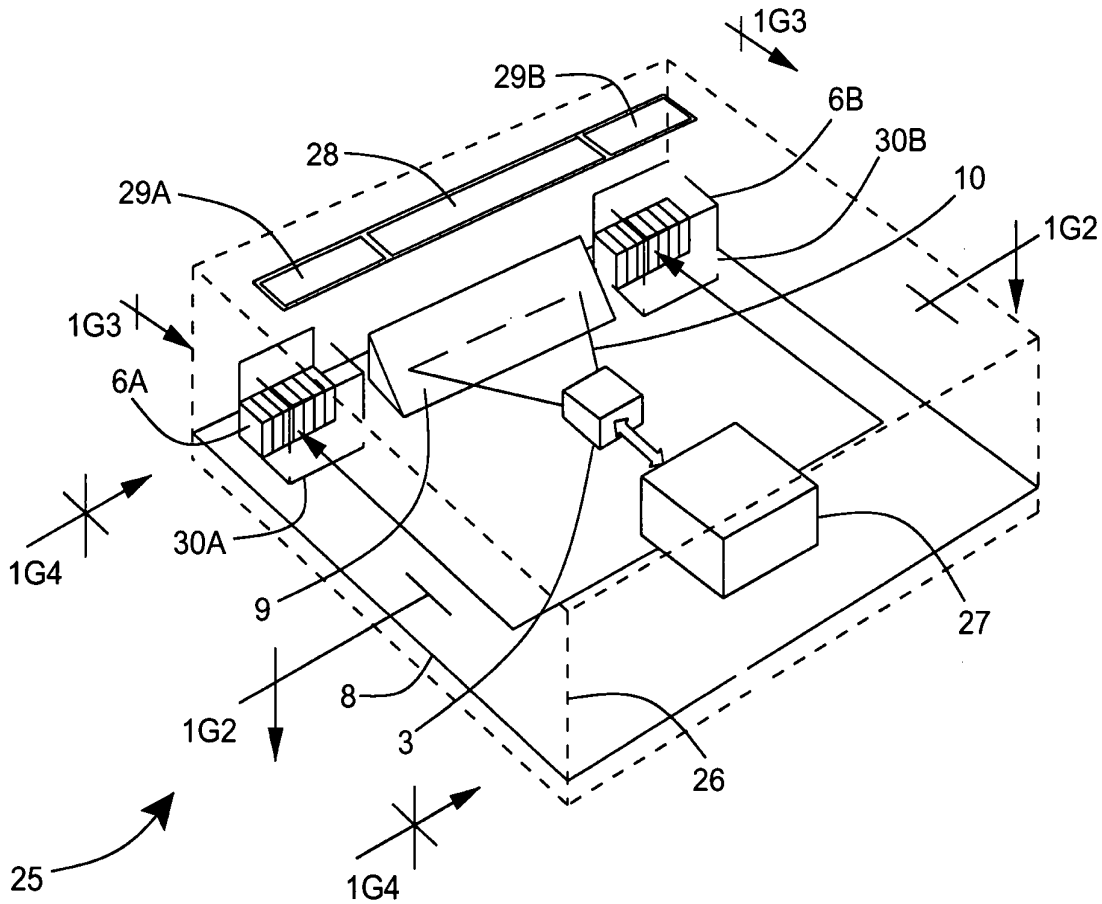


FIG. 1G1

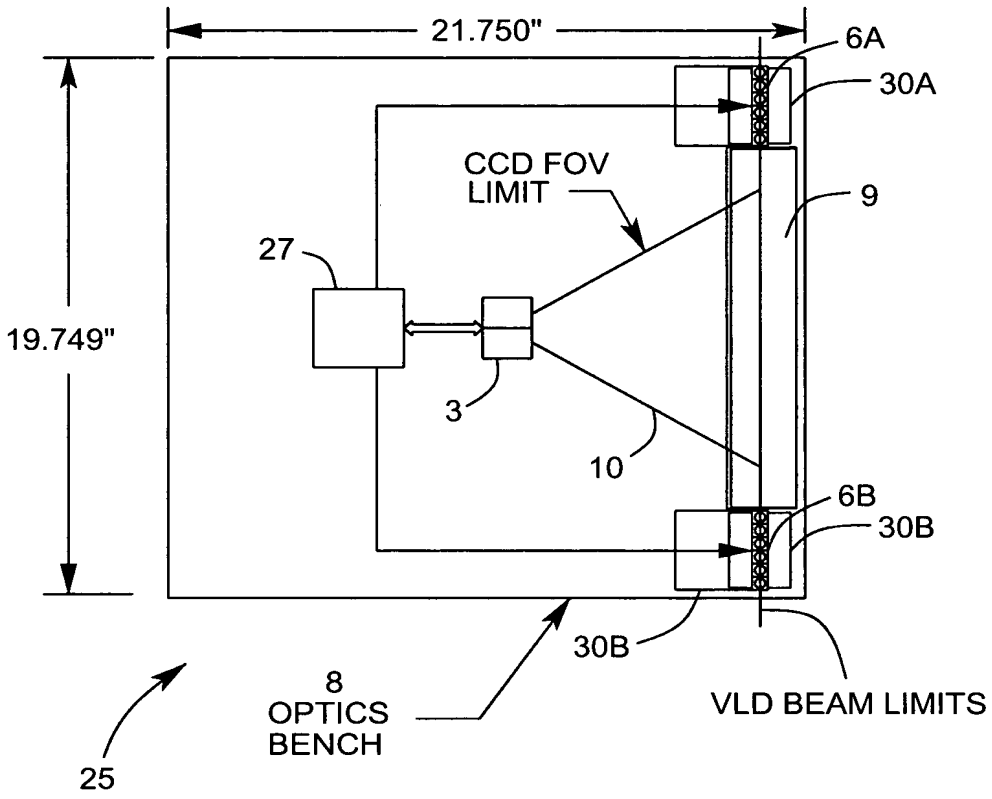

21.750"
19.749"
6A
30A
CCD FOV
LIMIT
9
27
3
10
6B
30B
30B
8
OPTICS
BENCH
VLD BEAM LIMITS
25

FIG. 1G2

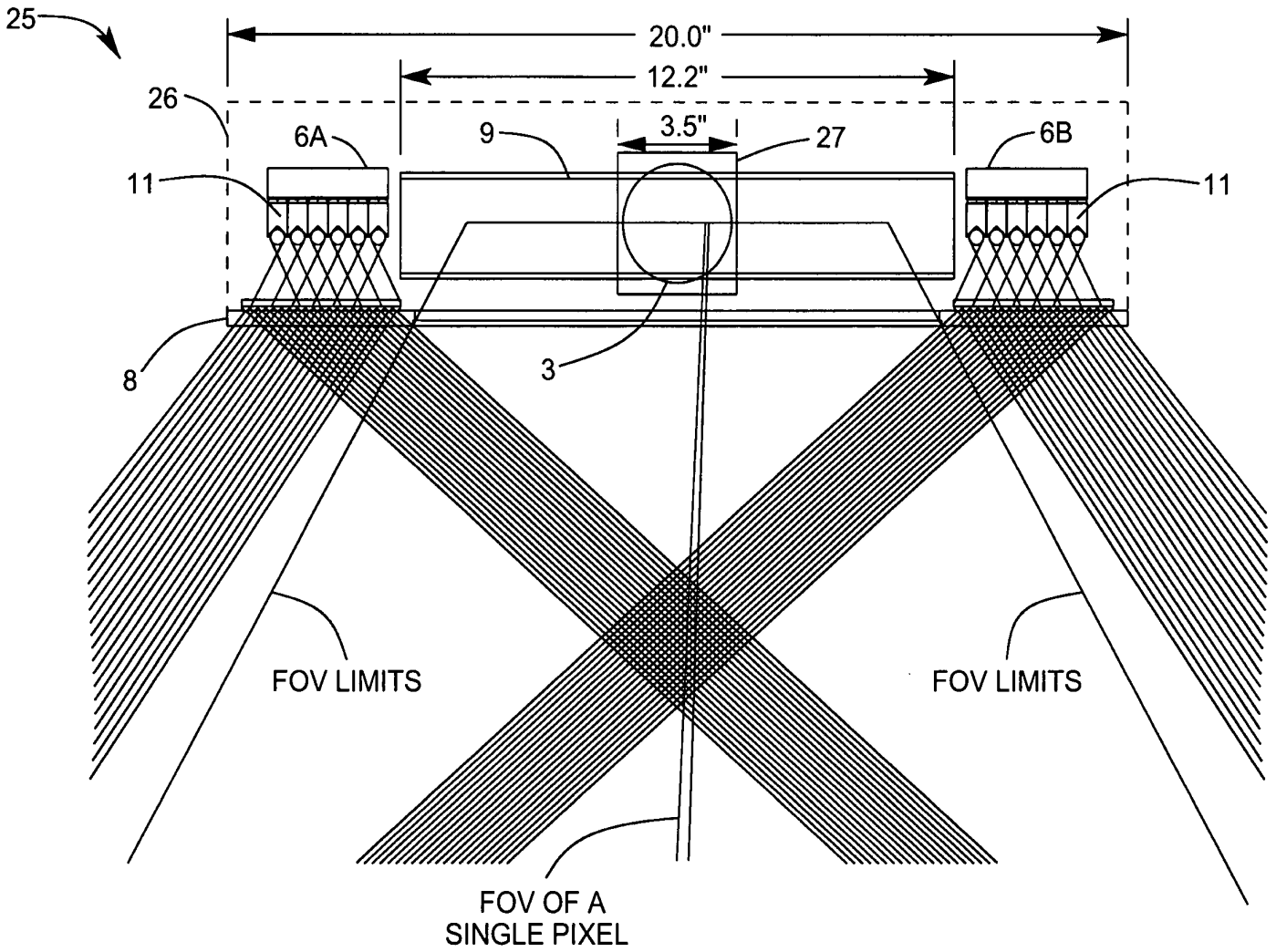

25
20.0"
12.2"
26
6A
9
3.5"
27
6B
11
11
8
3
FOV LIMITS
FOV LIMITS
FOV OF A
SINGLE PIXEL

FIG. 1G3A

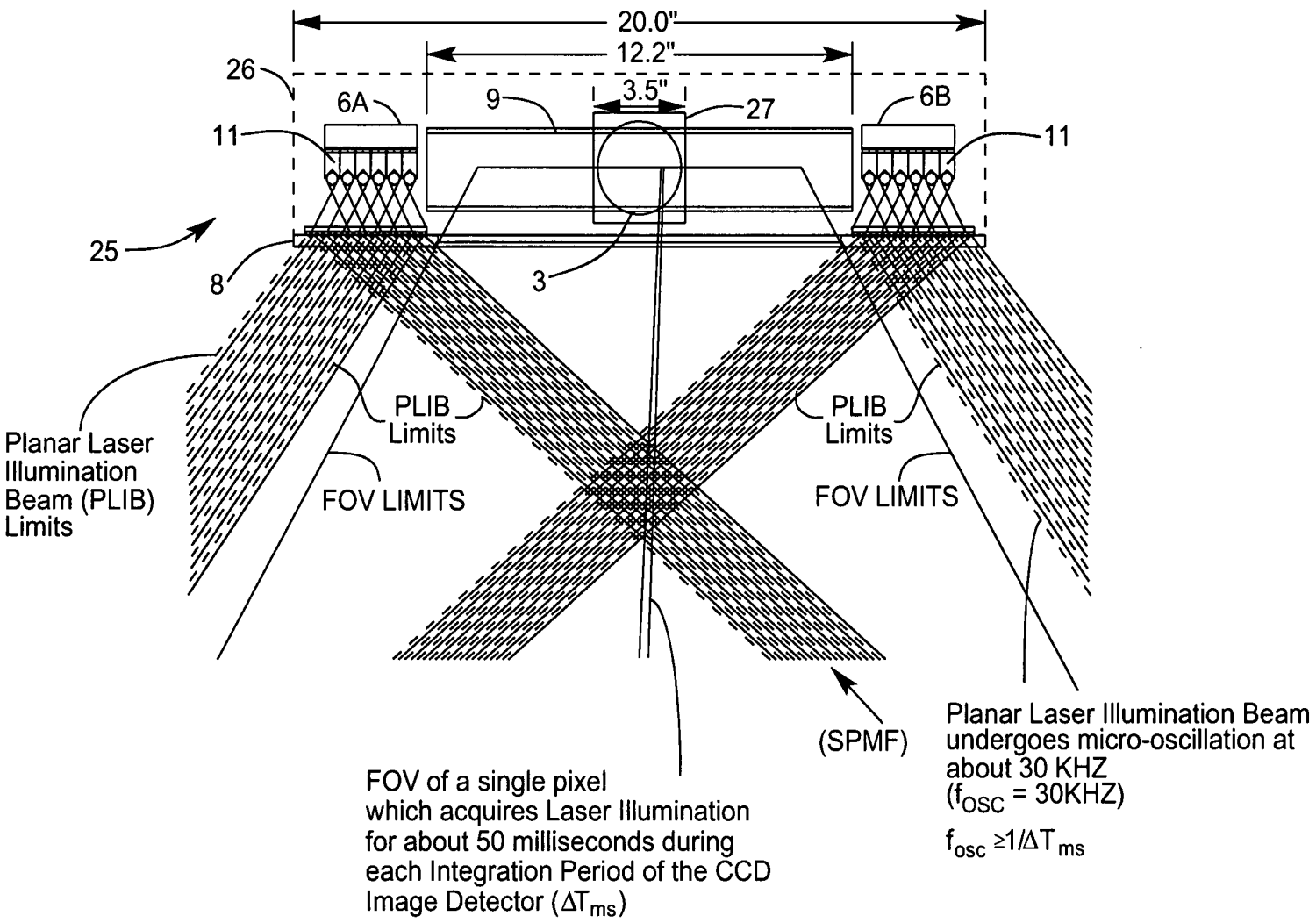

20.0"
12.2"
3.5"
26
6A
9
27
6B
11
11
25
8
3
PLIB
Limits
PLIB
Limits
Planar Laser
Illumination
Beam (PLIB)
Limits
FOV LIMITS
FOV LIMITS
(SPMF)
Planar Laser Illumination Beam
undergoes micro-oscillation at
about 30 KHZ
(f_{OSC} = 30KHZ)
$f_{osc} \geq 1/\Delta T_{ms}$
FOV of a single pixel
which acquires Laser Illumination
for about 50 milliseconds during
each Integration Period of the CCD
Image Detector (ΔT_{ms})

FIG. 1G3B

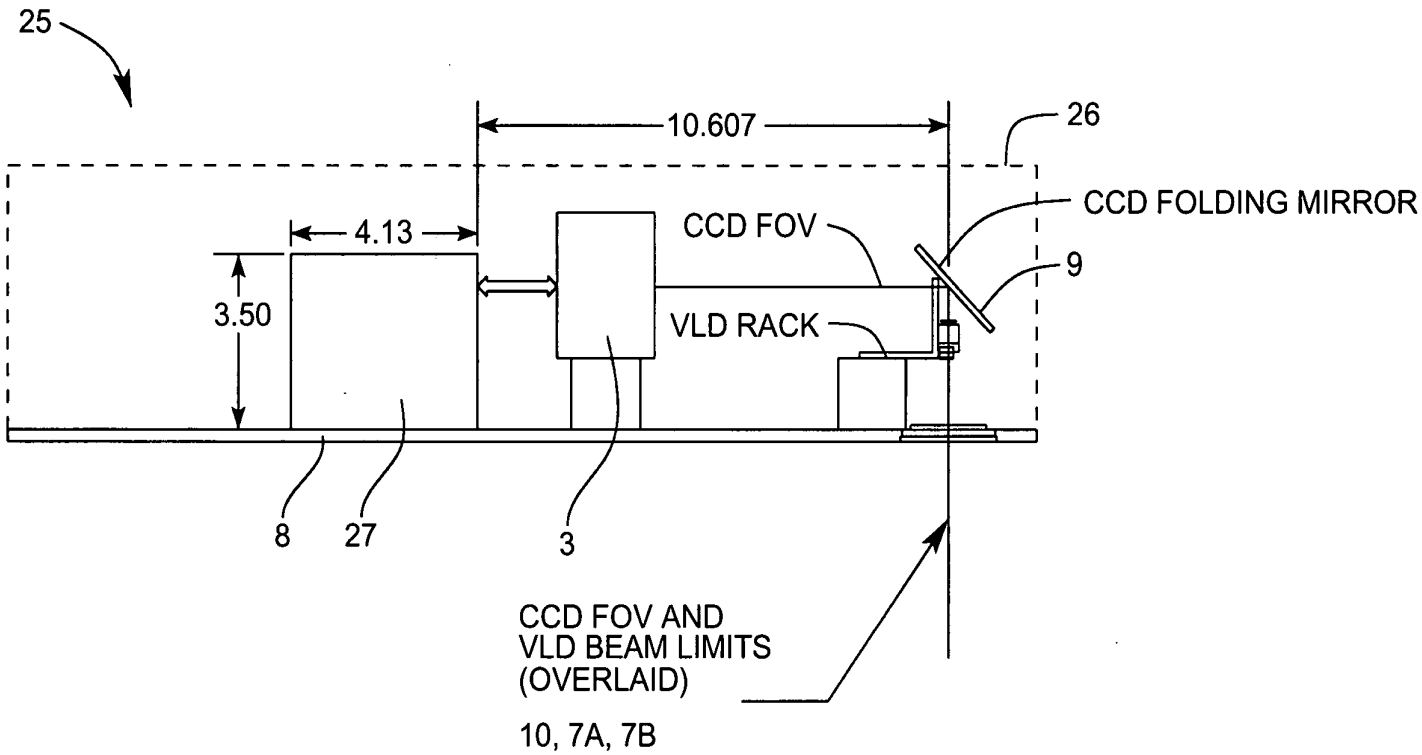

25
10.607
26
CCD FOLDING MIRROR
4.13
CCD FOV
9
3.50
VLD RACK
8
27
3
CCD FOV AND
VLD BEAM LIMITS
(OVERLAID)
10, 7A, 7B

FIG. 1G4

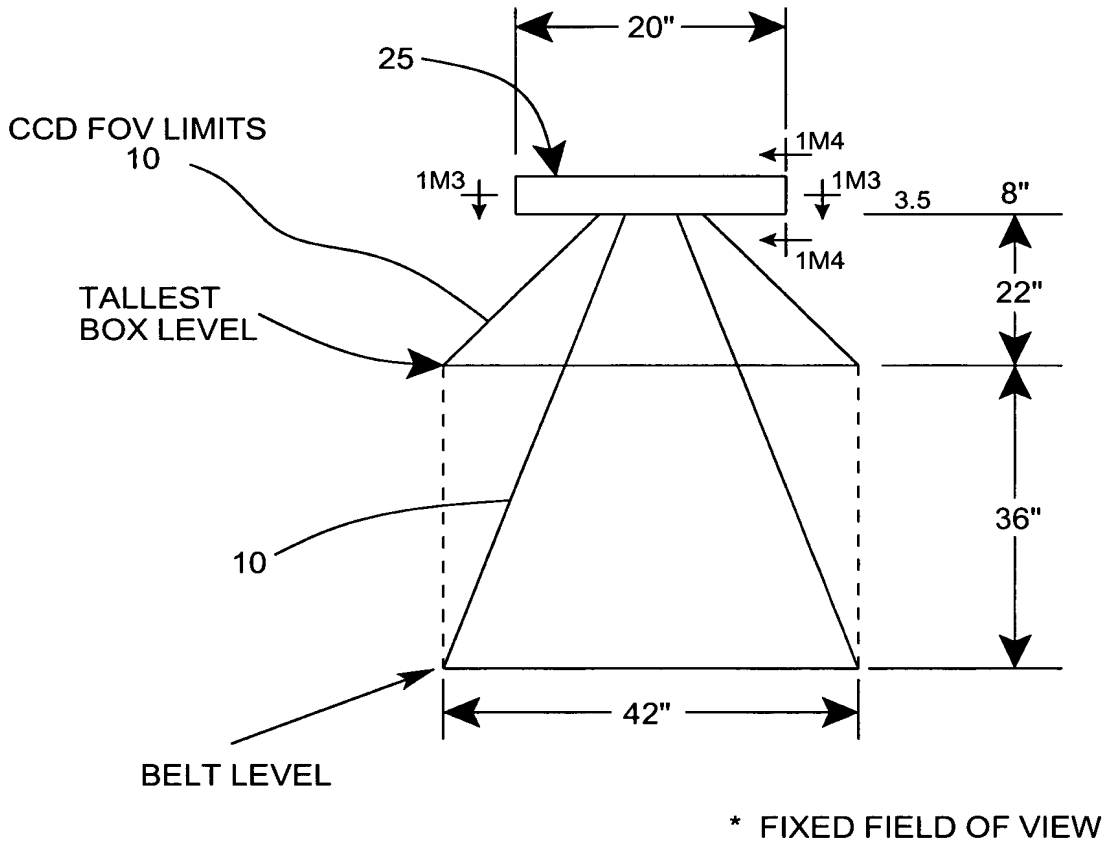

20"
25
CCD FOV LIMITS
10
1M4
1M3
1M3
3.5
8"
1M4
22"
TALLEST
BOX LEVEL
36"
10
42"
BELT LEVEL
* FIXED FIELD OF VIEW

FIG. 1G5

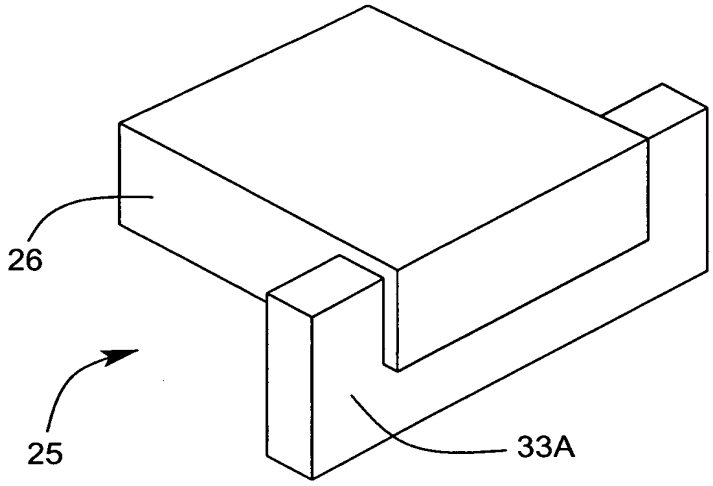


FIG. 1G6

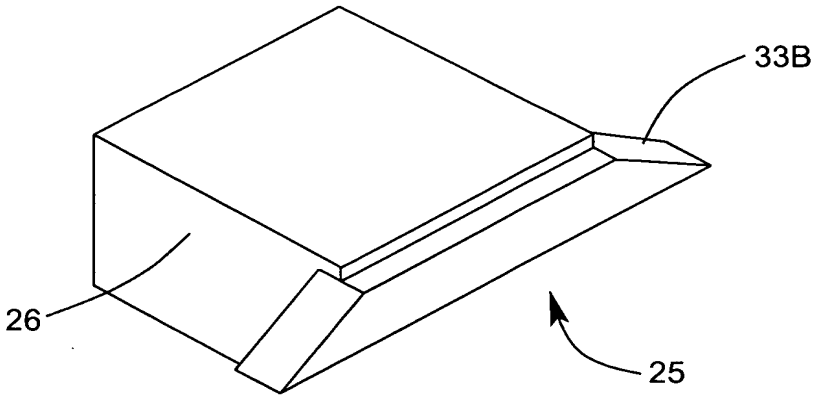


FIG. 1G7

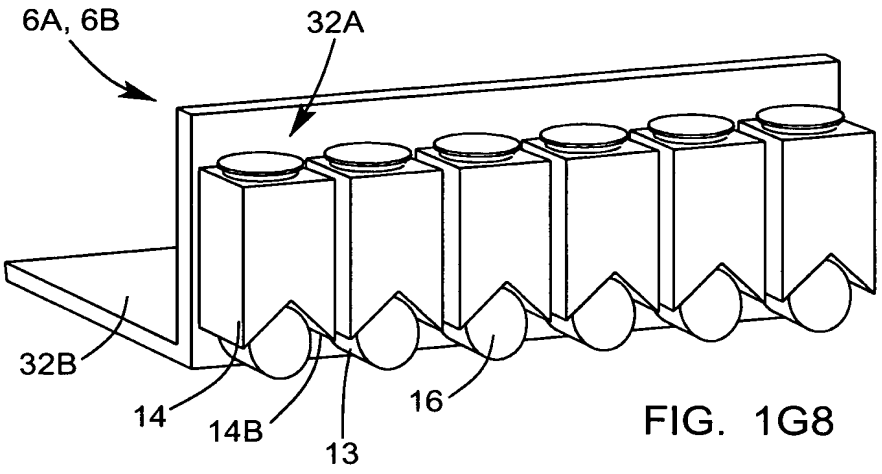


FIG. 1G8

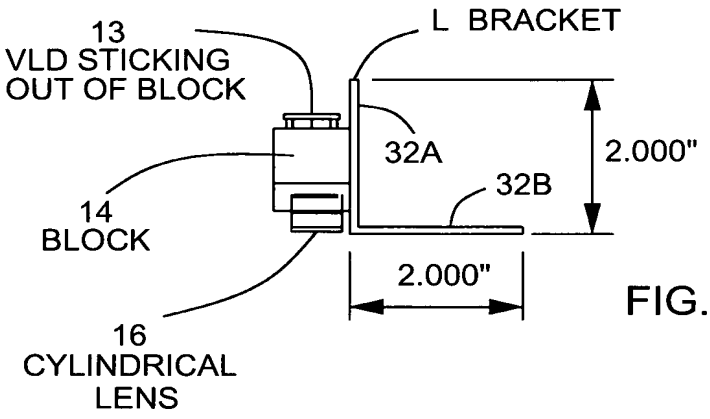


FIG. 1G9

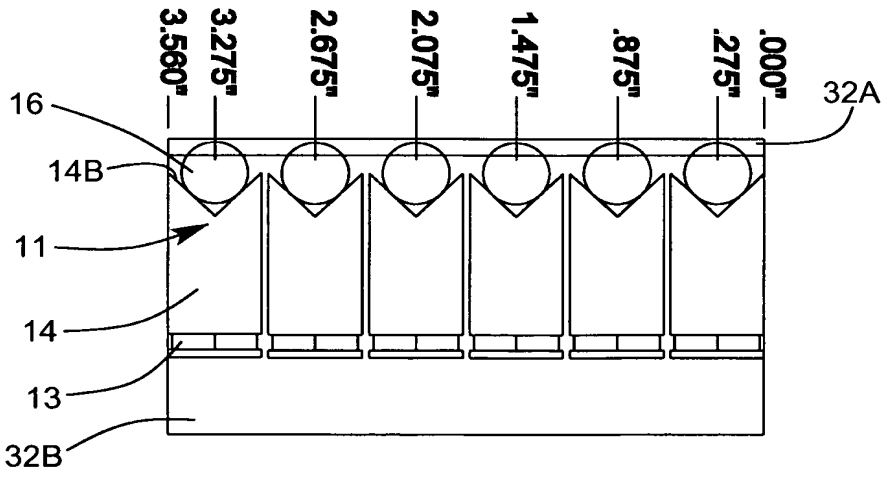


FIG. 1G10

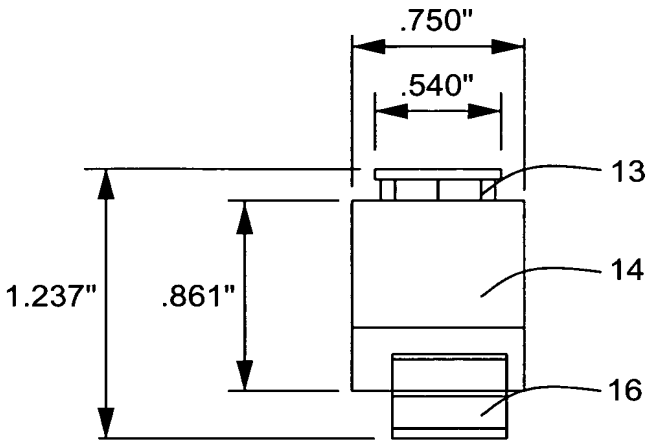


FIG. 1G11

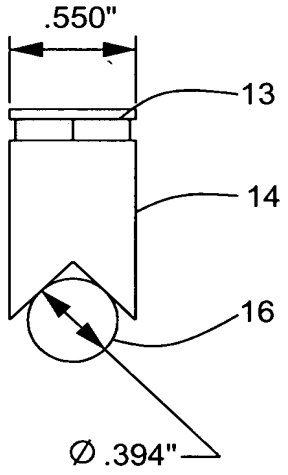


FIG. 1G12

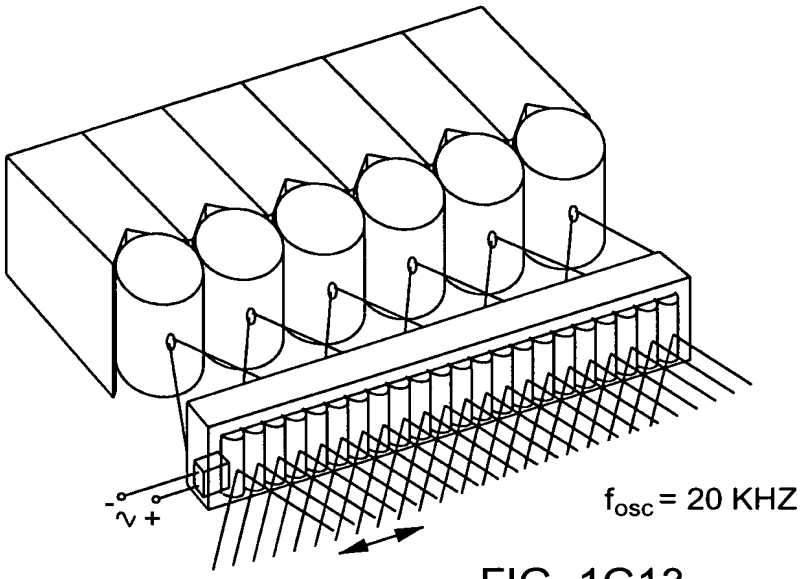


FIG. 1G13

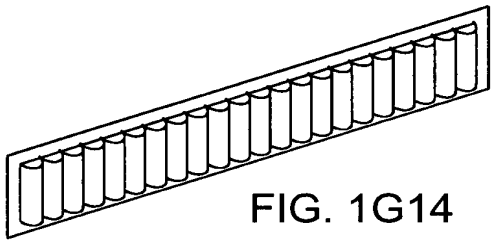


FIG. 1G14

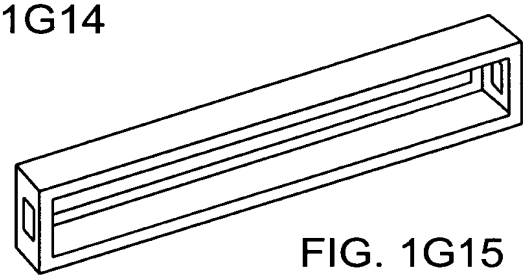


FIG. 1G15

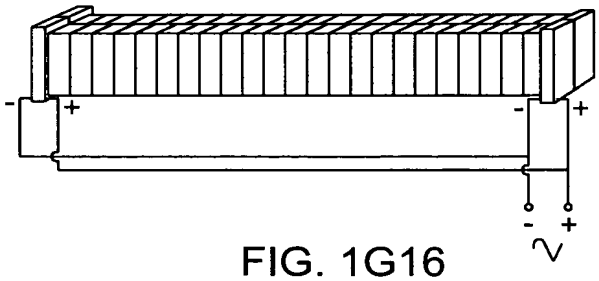


FIG. 1G16

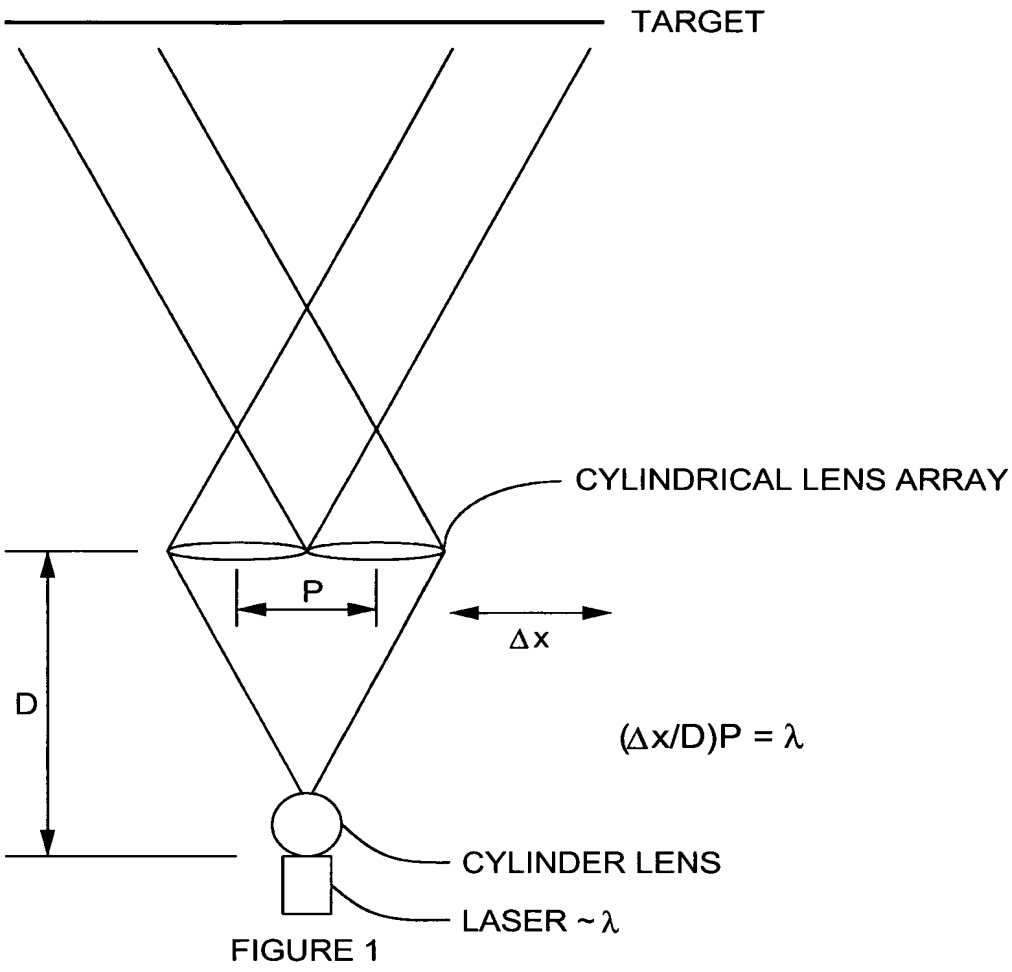


FIGURE 1

$$\Delta x \geq \frac{\lambda \cdot D}{P}$$

FIG. 1G13A

TO BE INSERTED HERE

FIG. 1G13B1 AND

FIG. 1G13B2

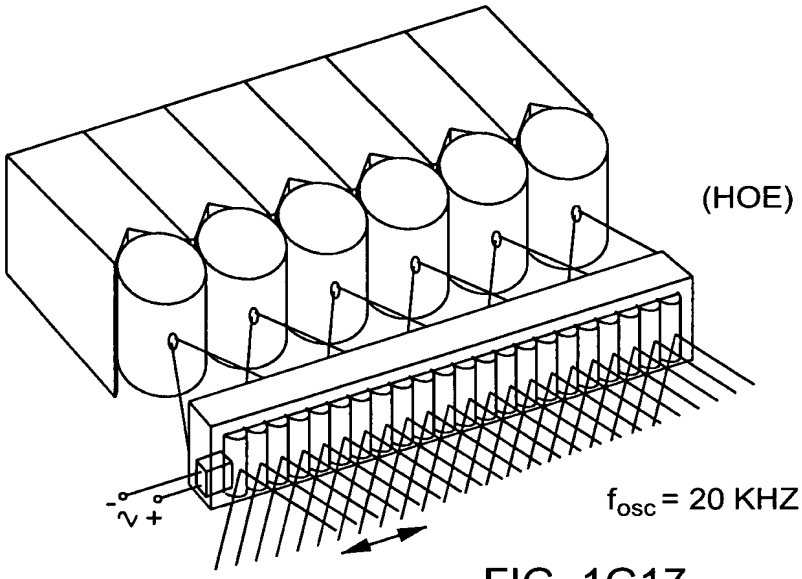


FIG. 1G17

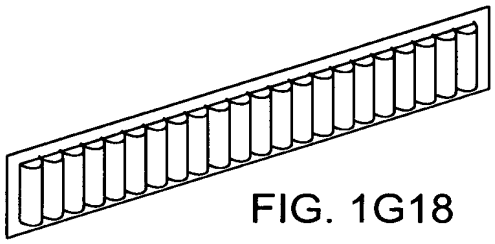


FIG. 1G18

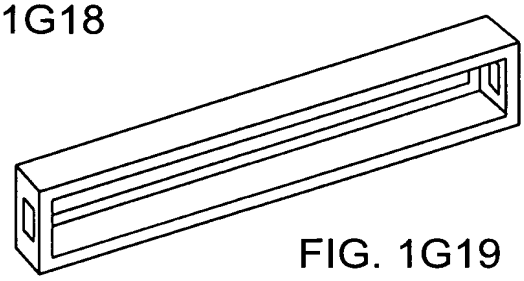


FIG. 1G19

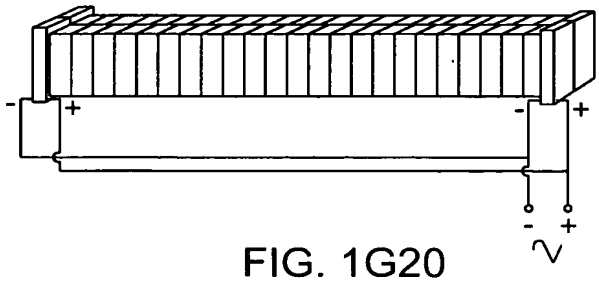


FIG. 1G20

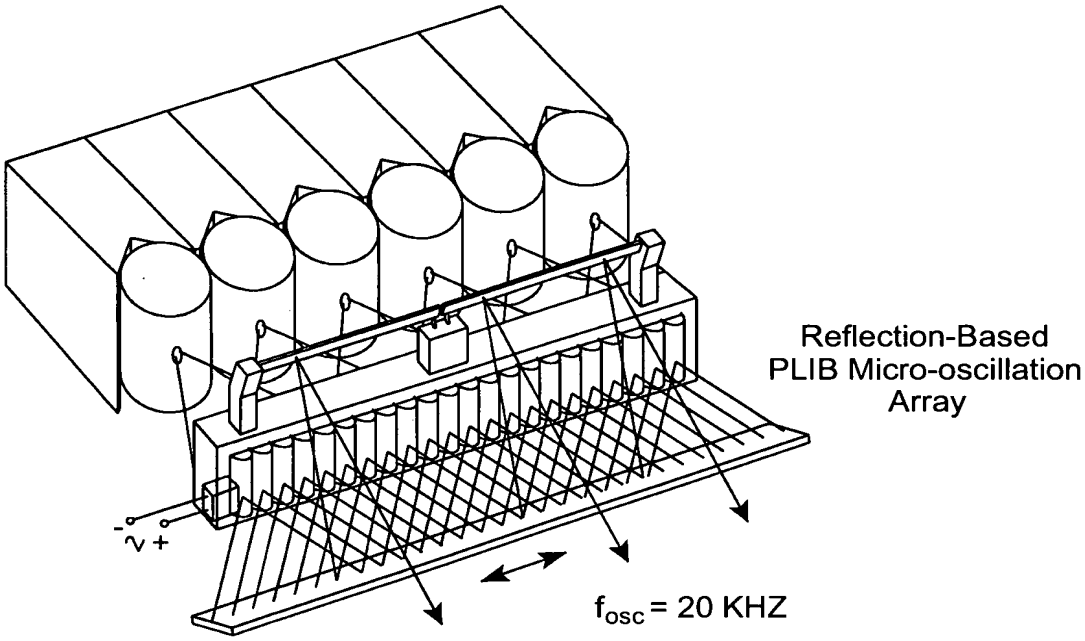


FIG. 1G21

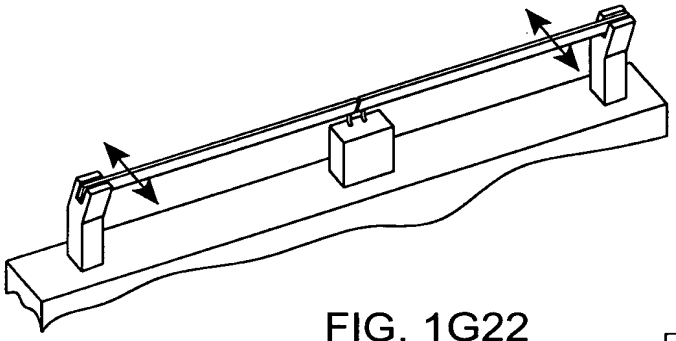


FIG. 1G22

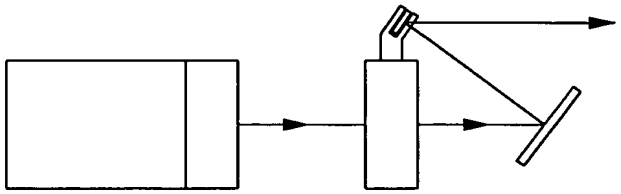


FIG. 1G23

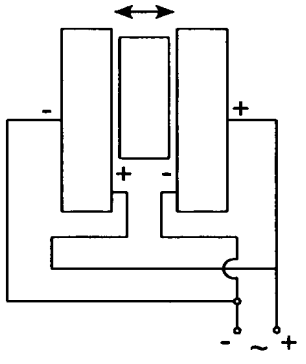


FIG. 1G24

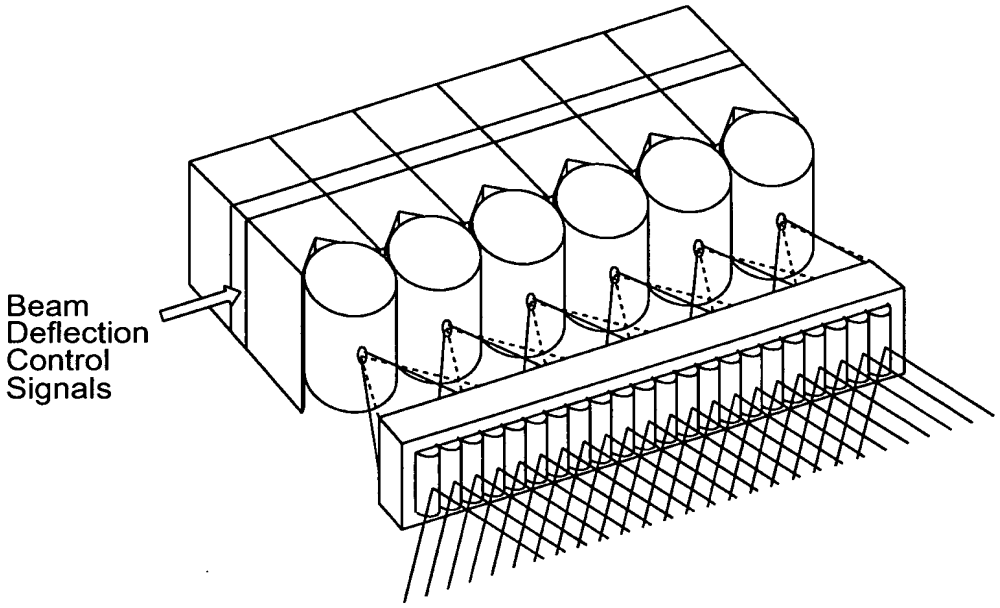


FIG. 1G25

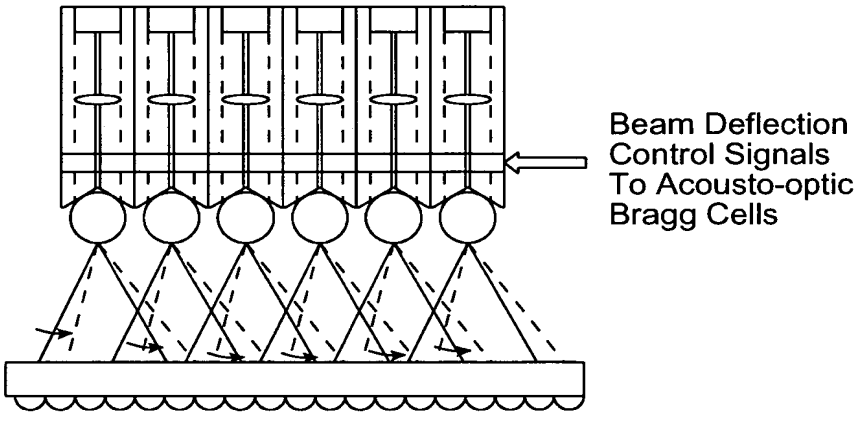


FIG. 1G26

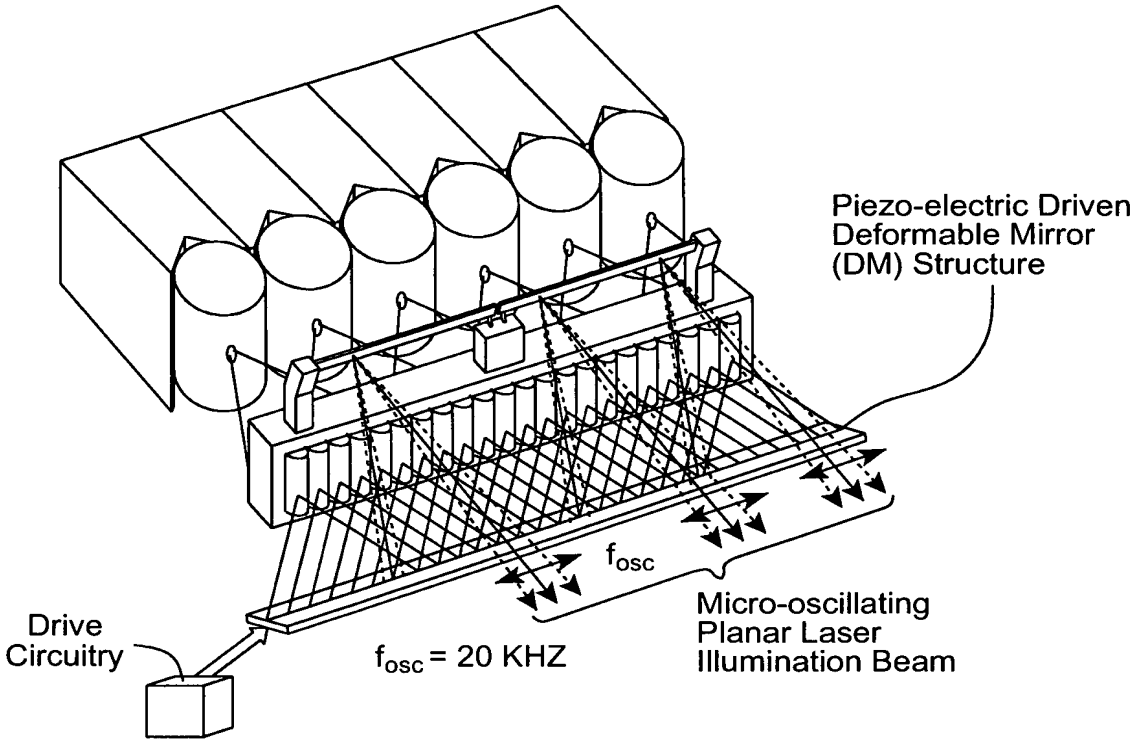


FIG. 1G27

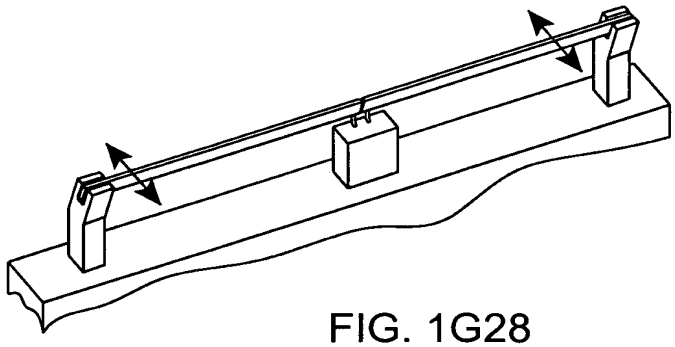


FIG. 1G28

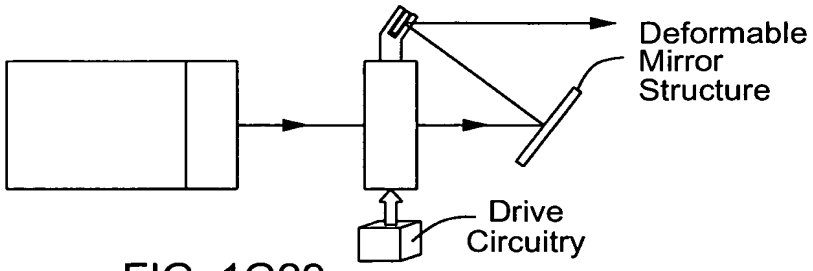


FIG. 1G29

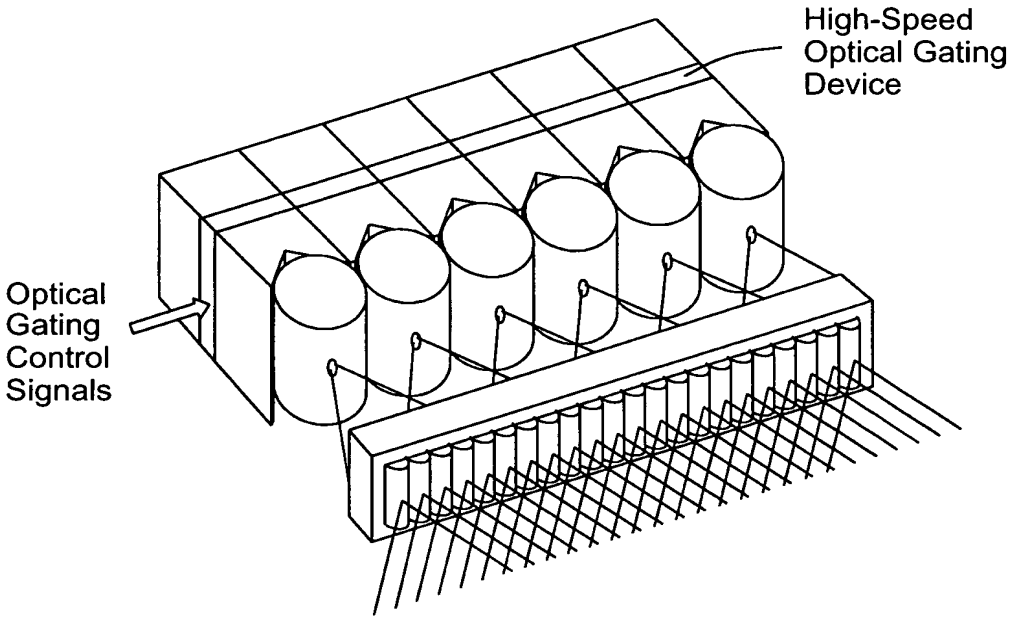


FIG. 1G30

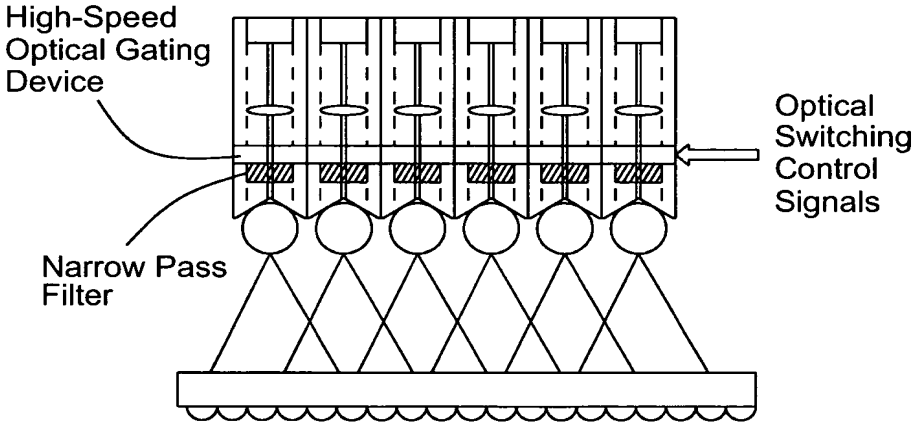


FIG. 1G31

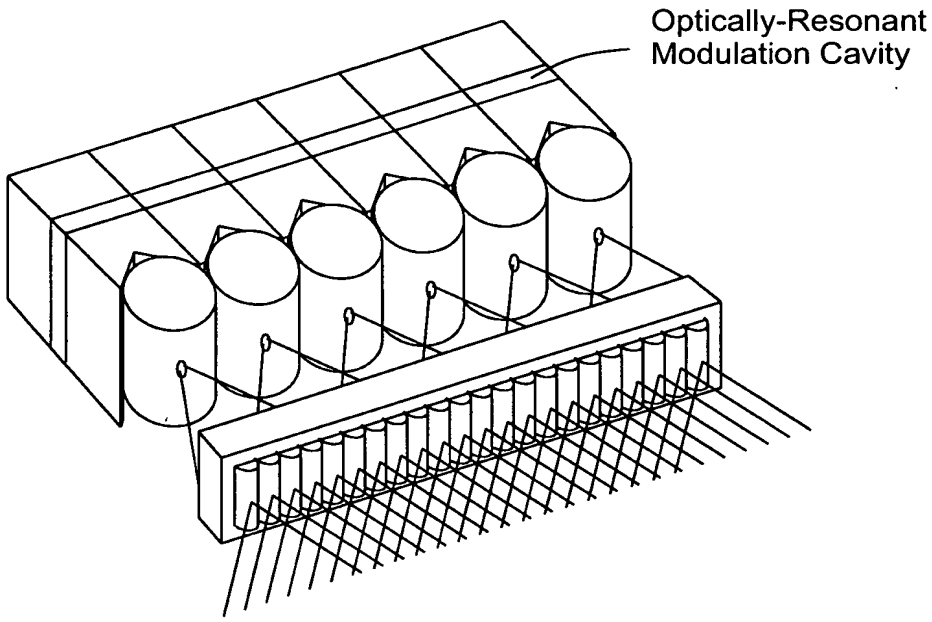


FIG. 1G32

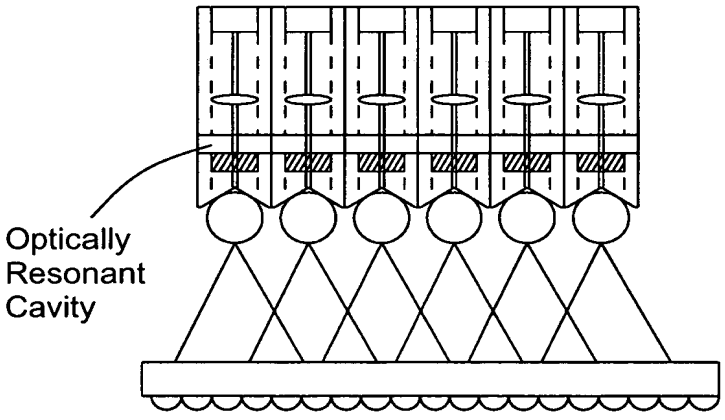


FIG. 1G33

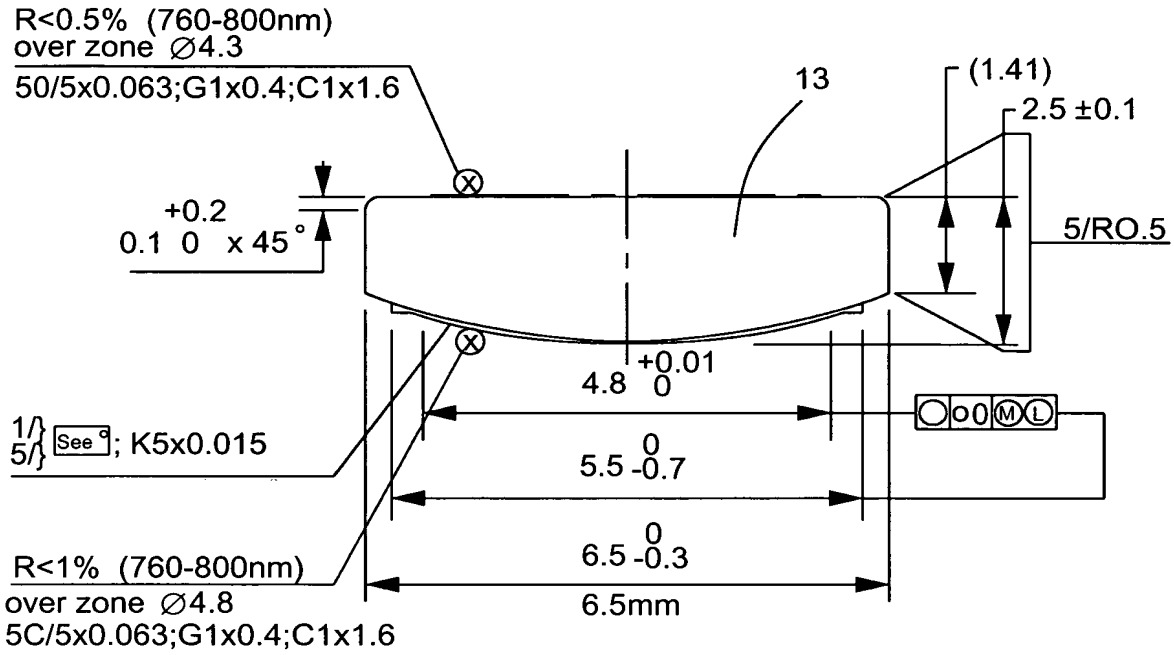


FIG. 1H1

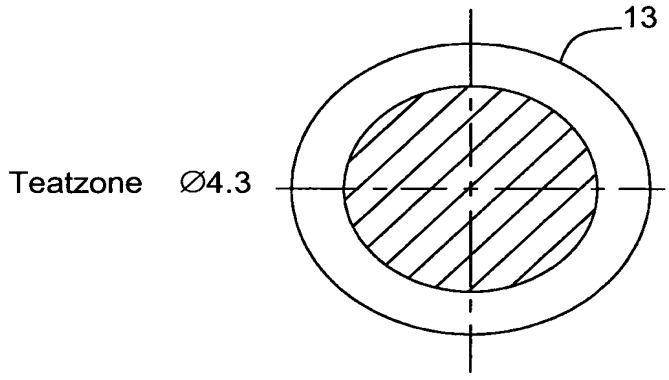


FIG. 1H2

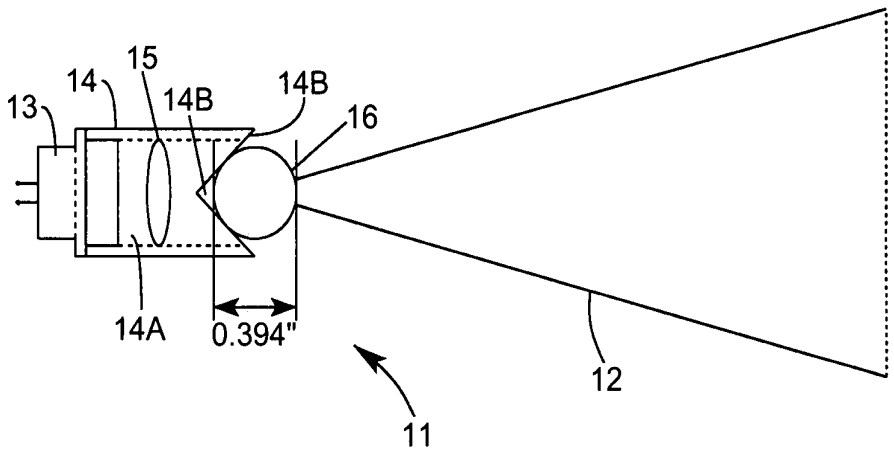


FIG. 1I1

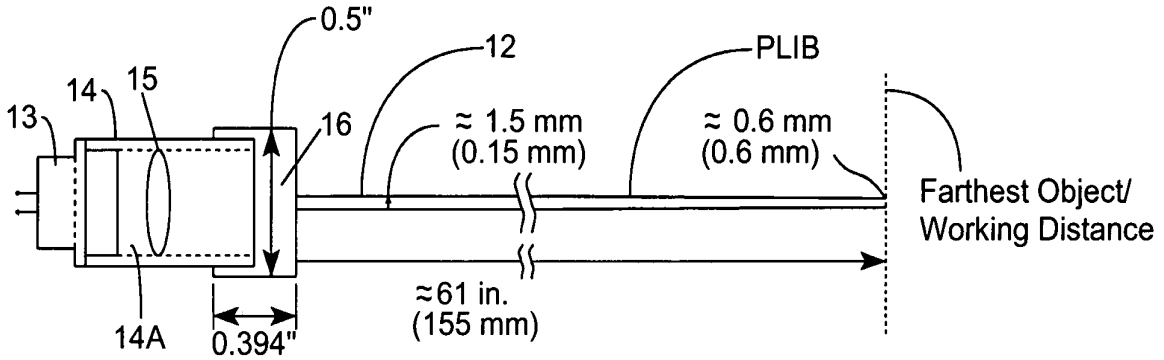


FIG. 1I2

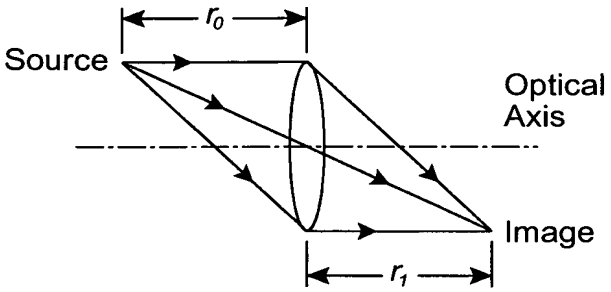


FIG. 1J1

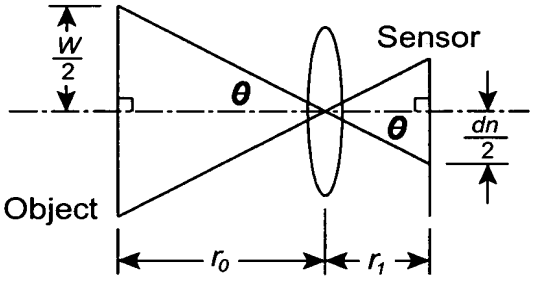


FIG. 1J2

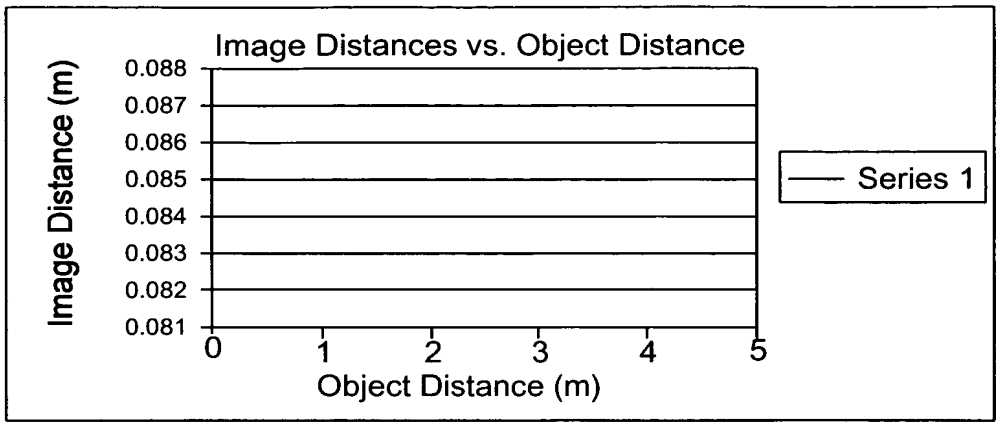


FIG. 1J3

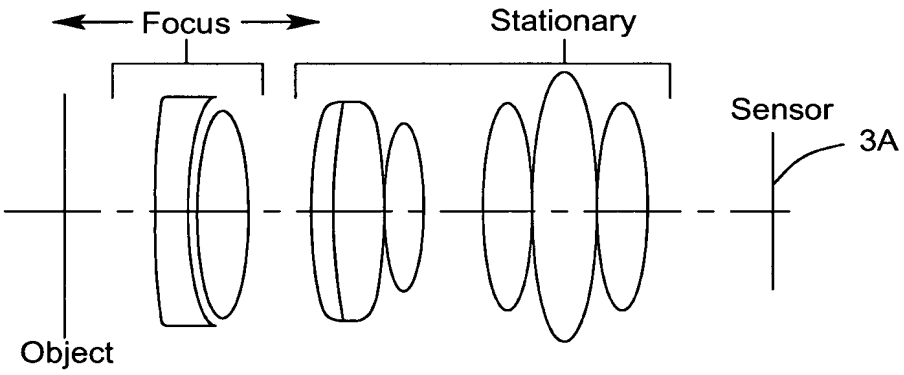


FIG. 1J4

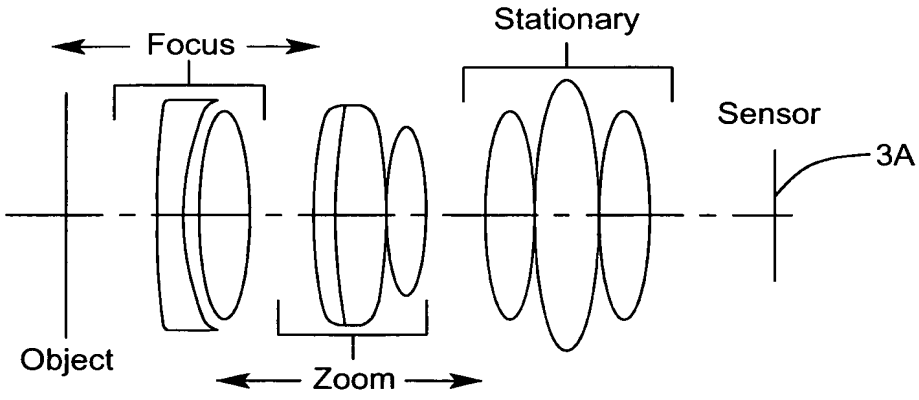


FIG. 1J5

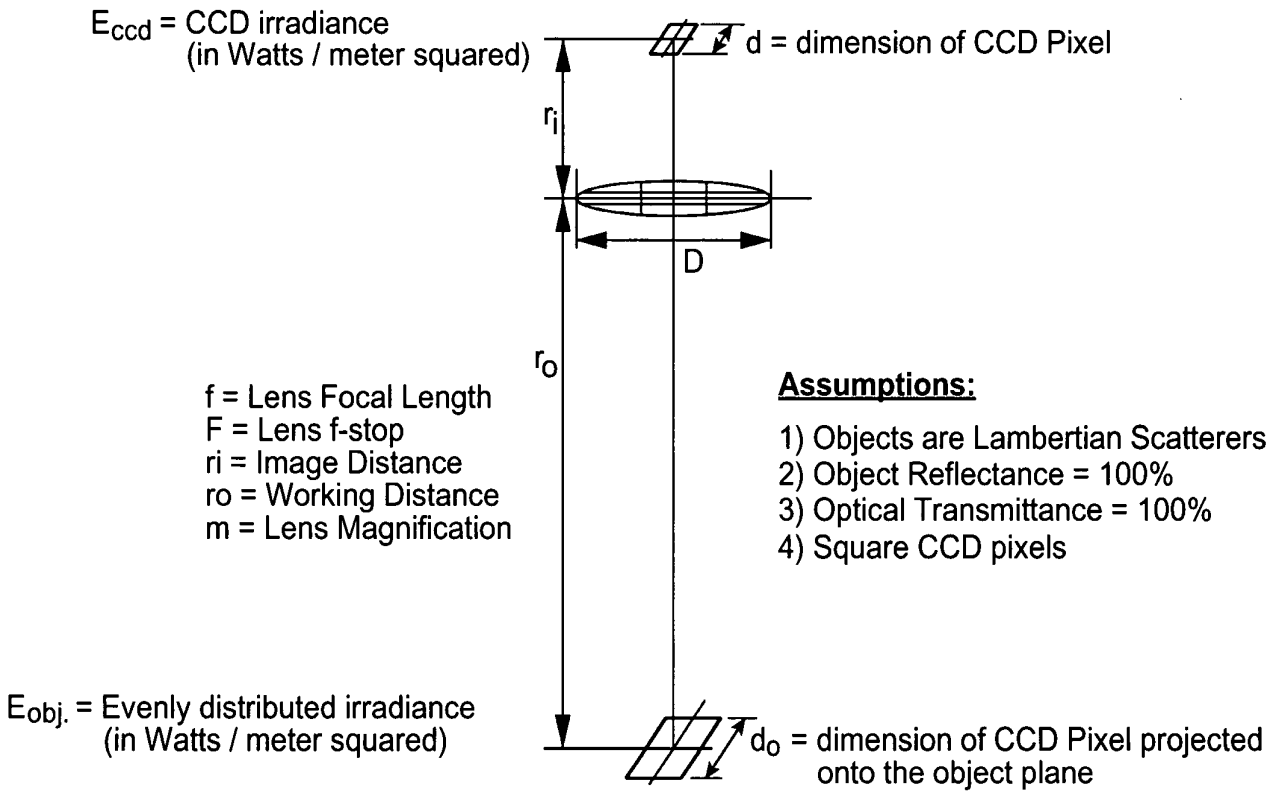

E_{ccd} = CCD irradiance
(in Watts / meter squared)
d = dimension of CCD Pixel
r_i
D
r_o
f = Lens Focal Length
F = Lens f-stop
ri = Image Distance
ro = Working Distance
m = Lens Magnification
Assumptions:
1) Objects are Lambertian Scatterers
2) Object Reflectance = 100%
3) Optical Transmittance = 100%
4) Square CCD pixels
$E_{obj.}$ = Evenly distributed irradiance
(in Watts / meter squared)
d_o = dimension of CCD Pixel projected
onto the object plane
CCD-Based Scanner

FIG. 1J6

Fixed Focal Length

Lens Cases

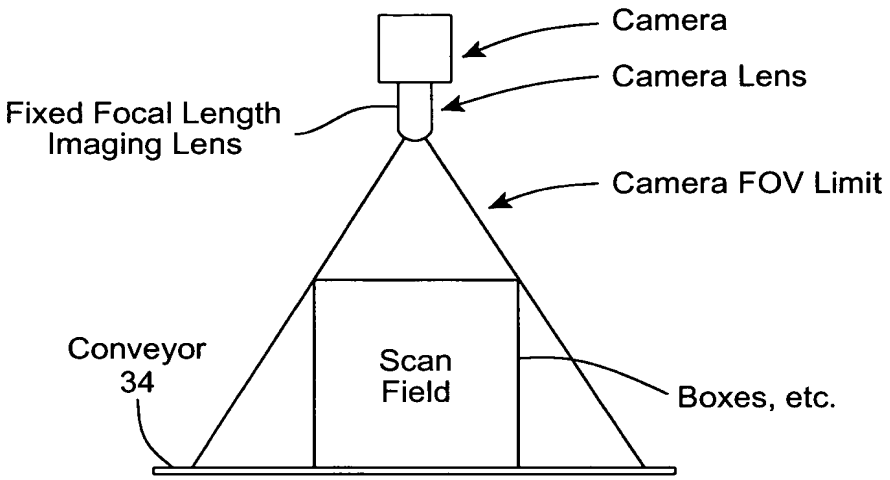


FIG. 1K1

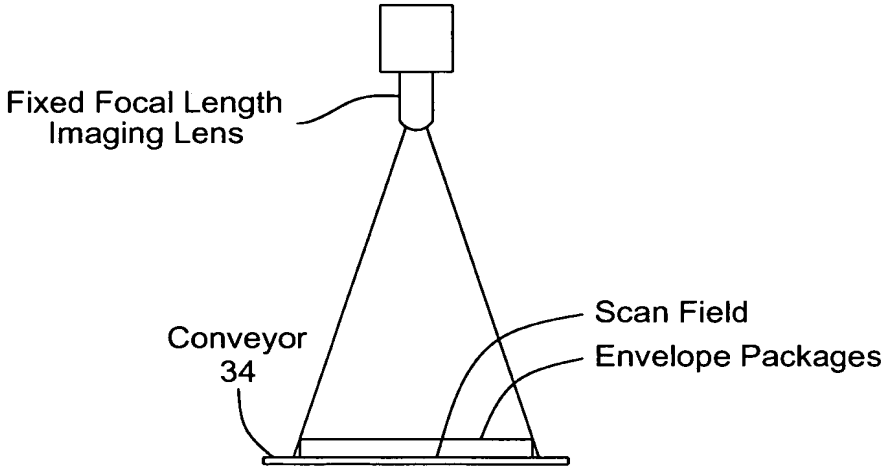


FIG. 1K2

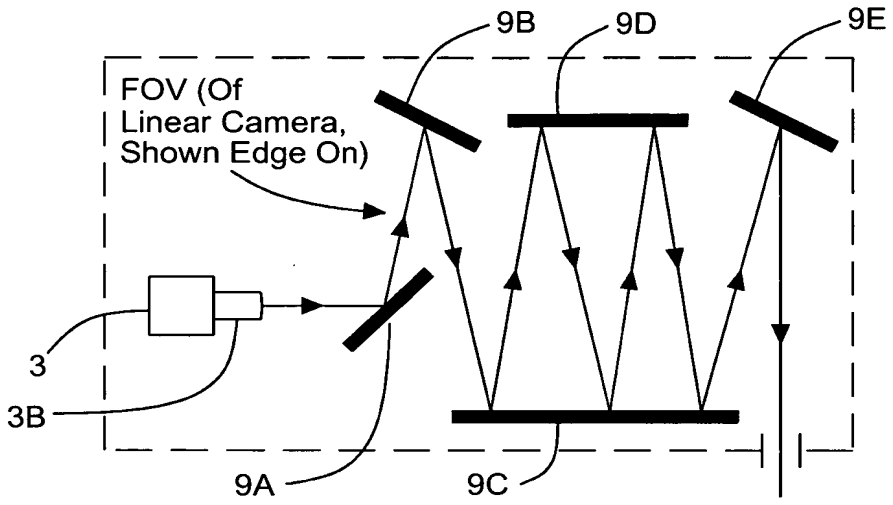


FIG. 1L1

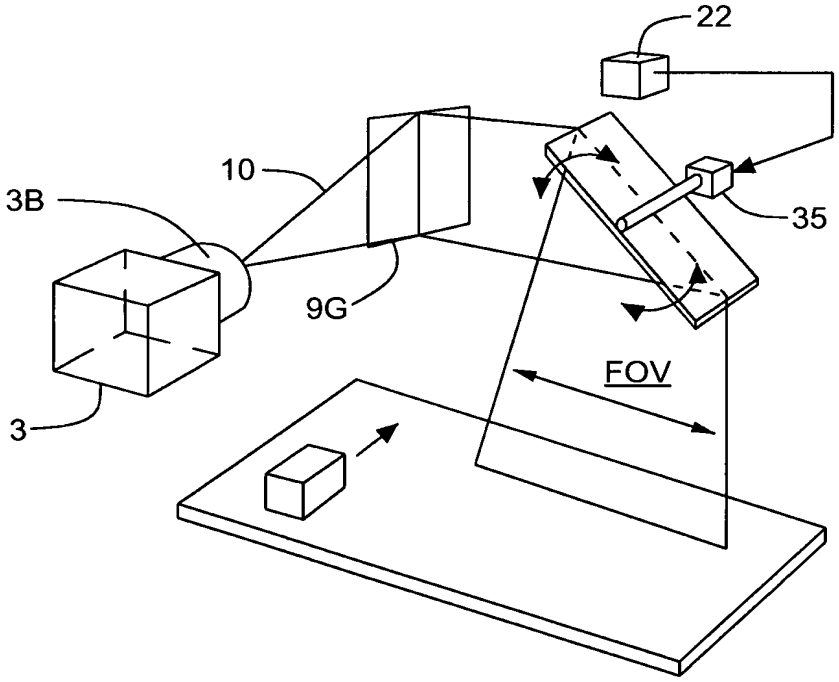


FIG. 1L2

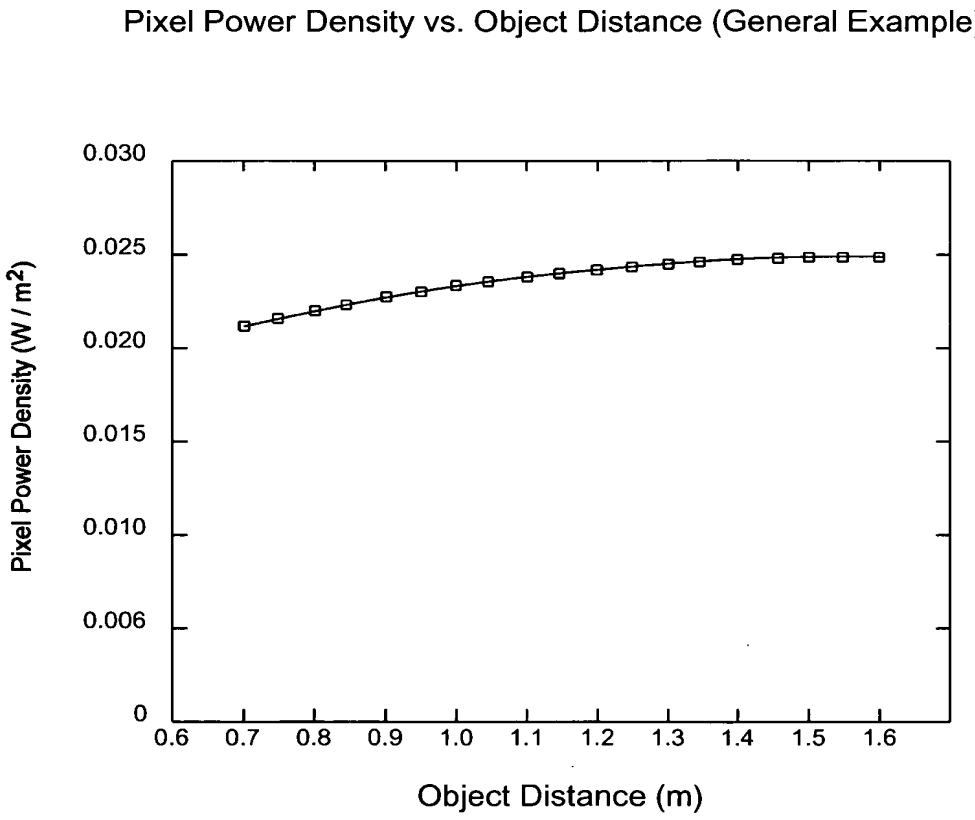

Pixel Power Density vs. Object Distance (General Example)
Pixel Power Density (W / m2)
0.030
0.025
0.020
0.015
0.010
0.006
0
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
Object Distance (m)

FIG. 1M1

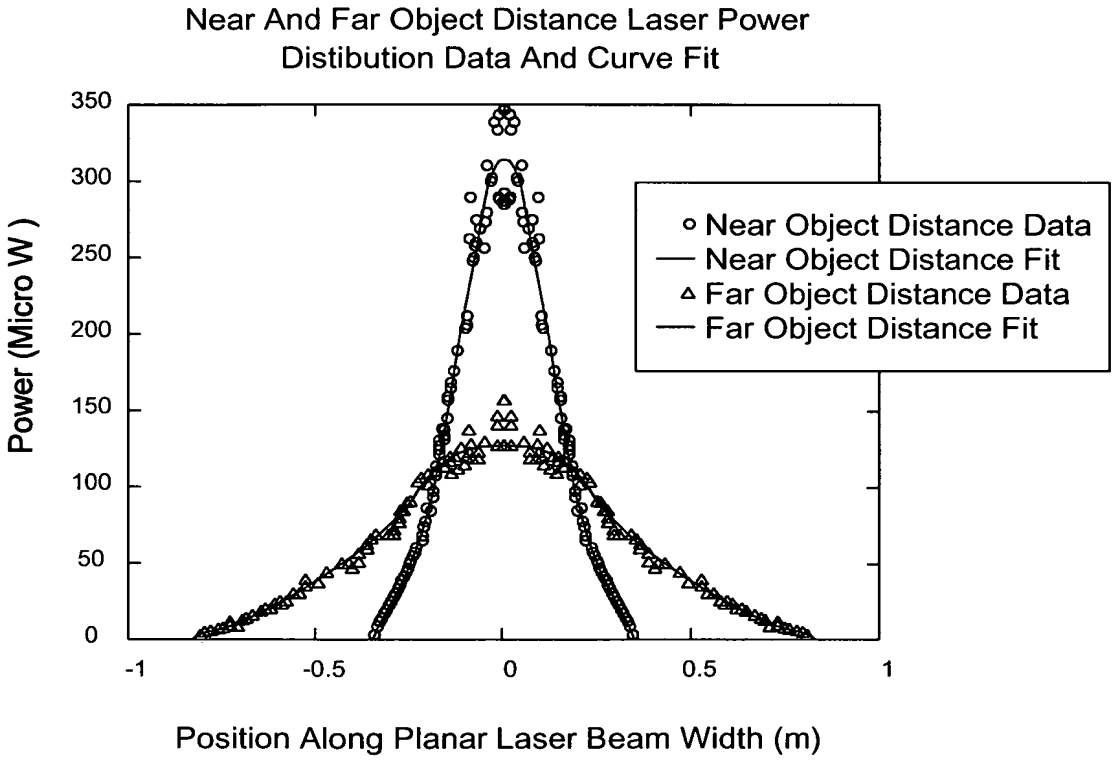

Near And Far Object Distance Laser Power
Distibution Data And Curve Fit
Power (Micro W)
350
300
250
200
150
100
50
0
-1
-0.5
0
0.5
1
Position Along Planar Laser Beam Width (m)
Near Object Distance Data
Near Object Distance Fit
Far Object Distance Data
Far Object Distance Fit

FIG. 1M2

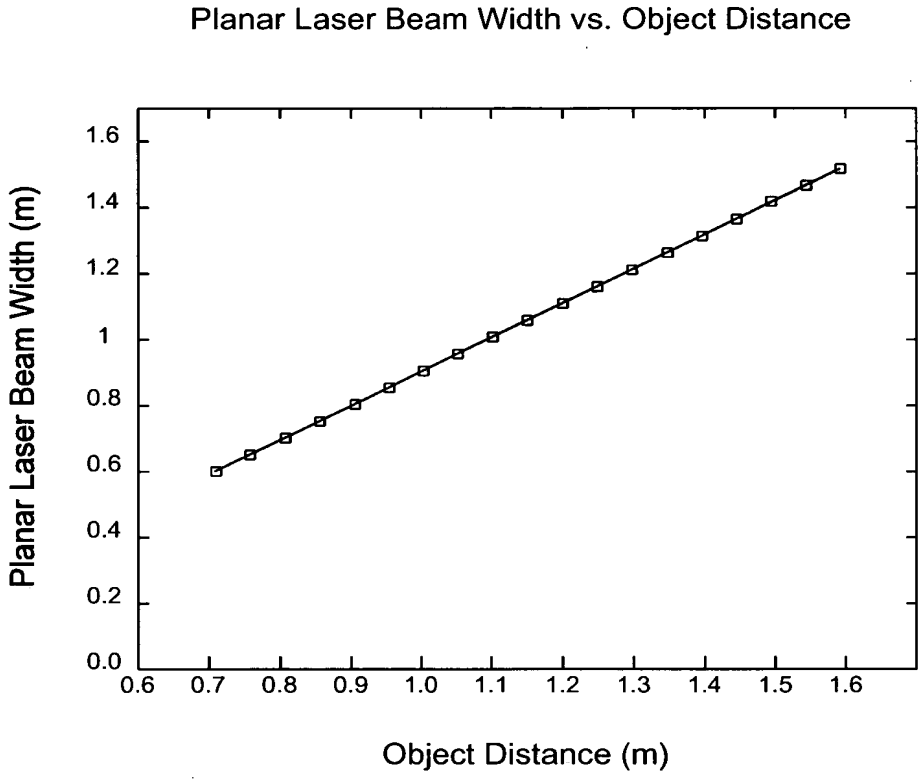

Planar Laser Beam Width vs. Object Distance
Planar Laser Beam Width (m)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0.0
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
Object Distance (m)

FIG. 1M3

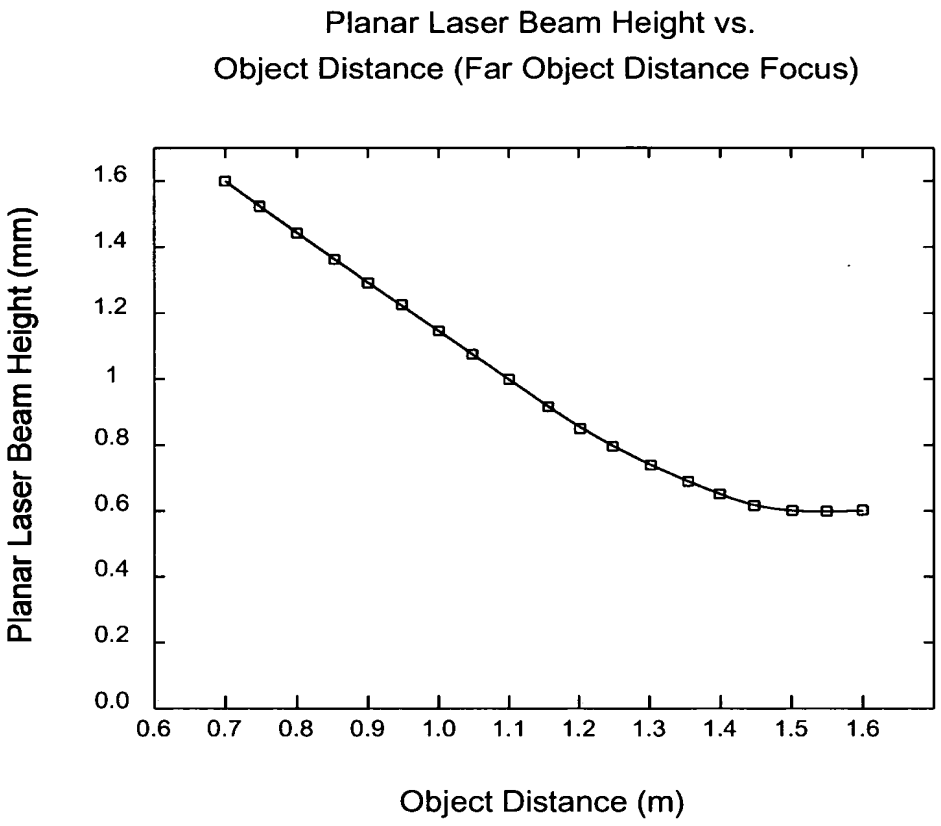

Planar Laser Beam Height vs.
Object Distance (Far Object Distance Focus)
Planar Laser Beam Height (mm)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0.0
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
Object Distance (m)

FIG. 1M4

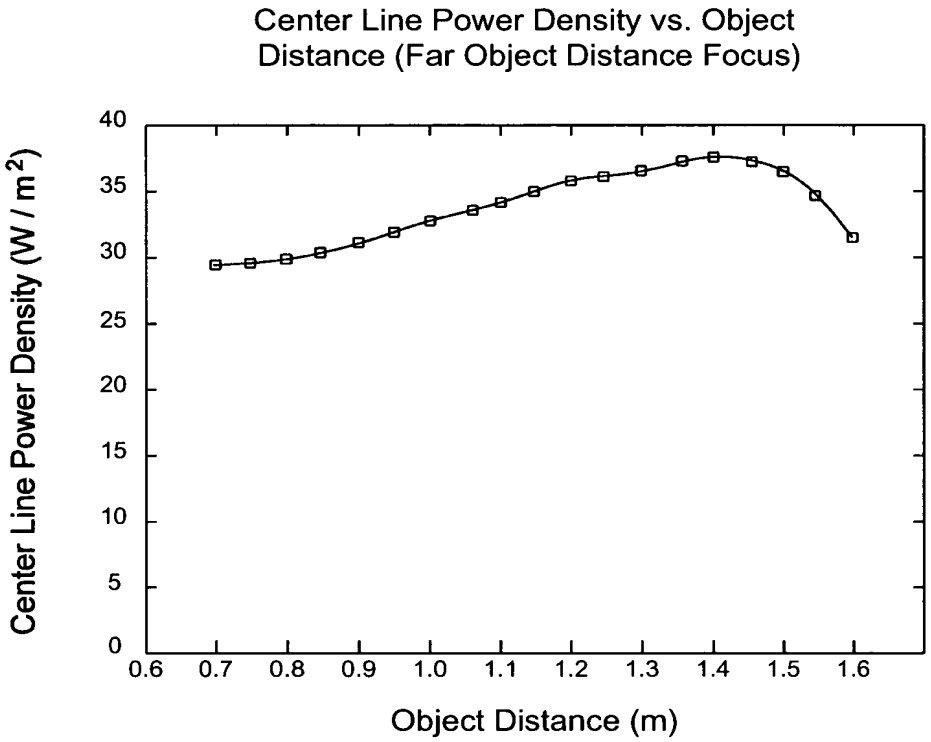

Center Line Power Density vs. Object Distance (Far Object Distance Focus)
Center Line Power Density (W / m2)
40
35
30
25
20
15
10
5
0
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
Object Distance (m)

FIG. 1N

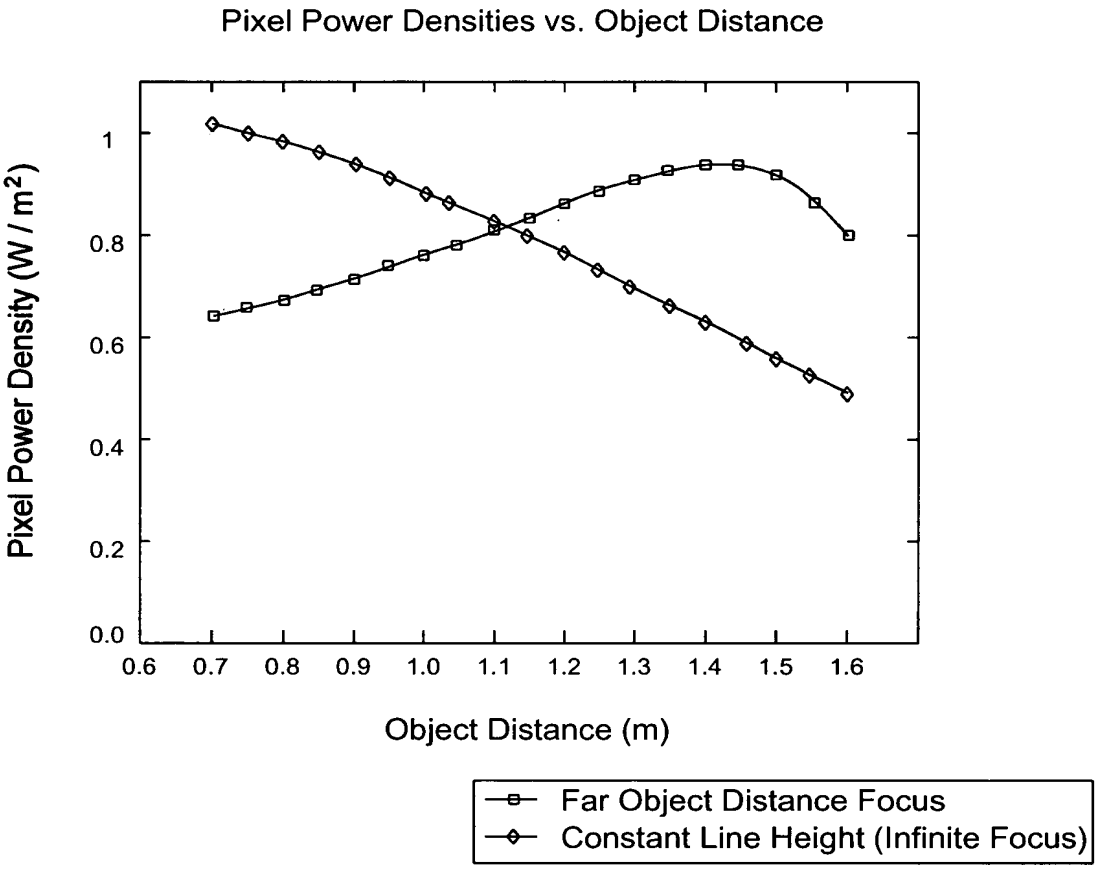

Pixel Power Densities vs. Object Distance
Pixel Power Density (W / m2)
1
0.8
0.6
0.4
0.2
0.0
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
Object Distance (m)
Far Object Distance Focus
Constant Line Height (Infinite Focus)

FIG. 1O

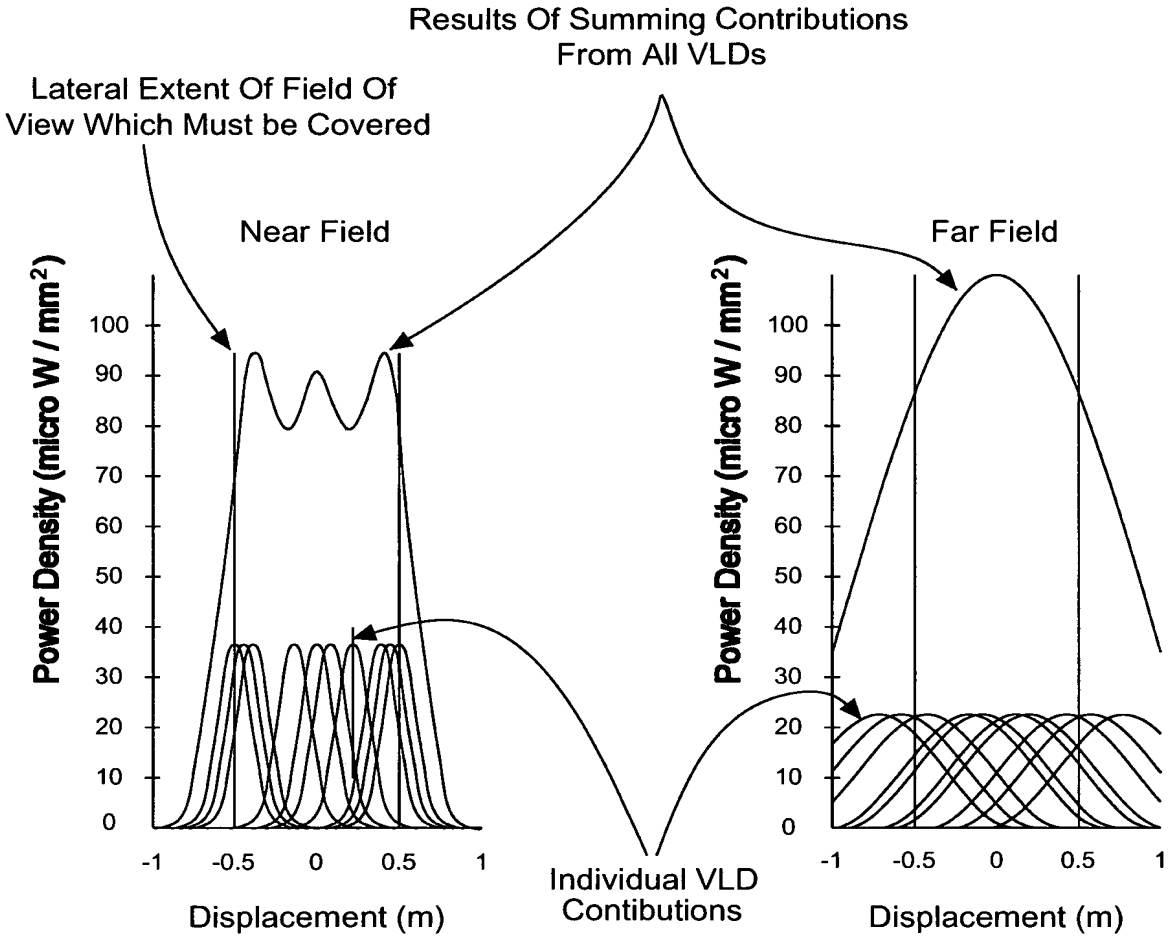


FIG. 1P1

FIG. 1P2

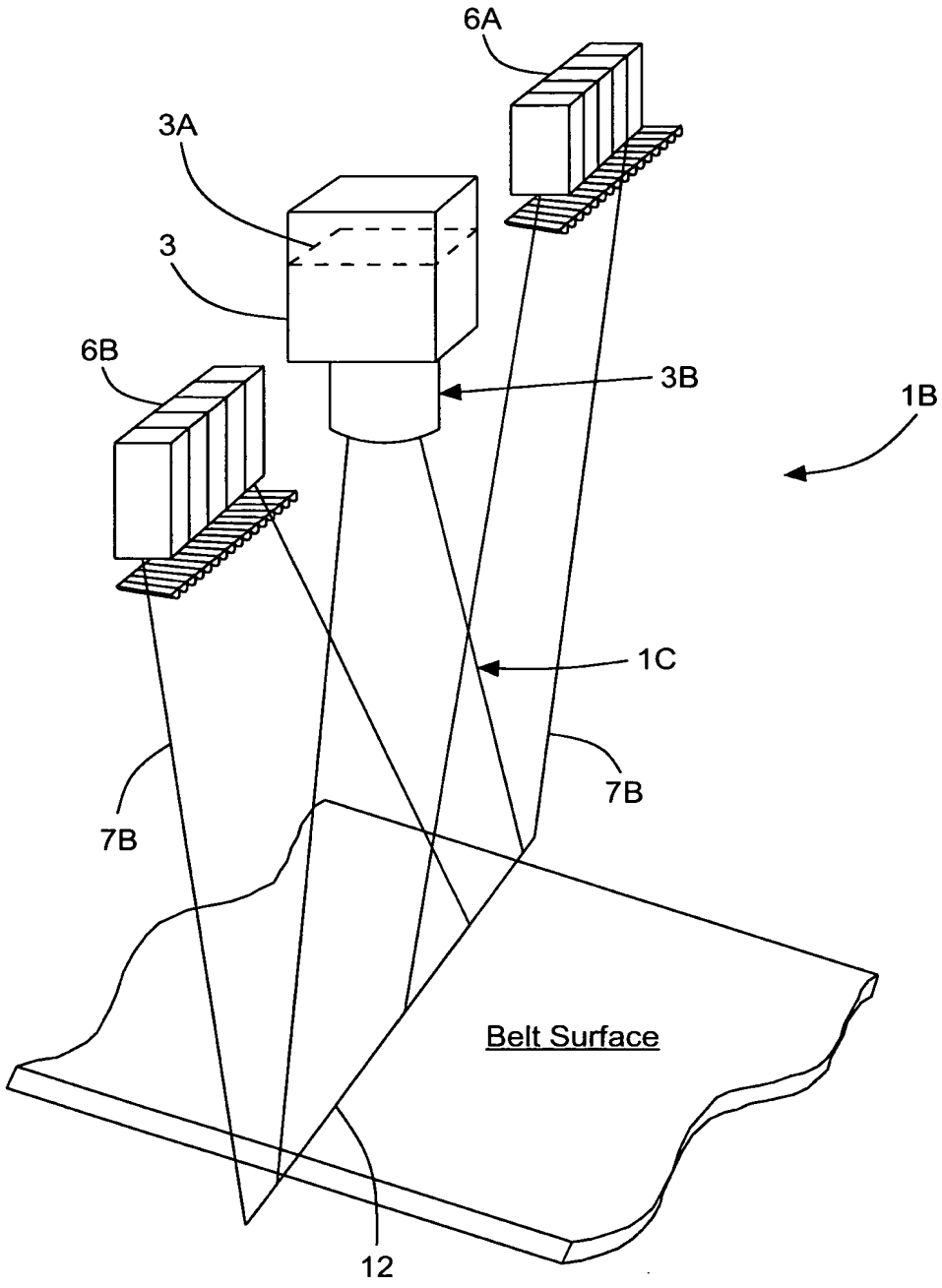


FIG. 1Q1

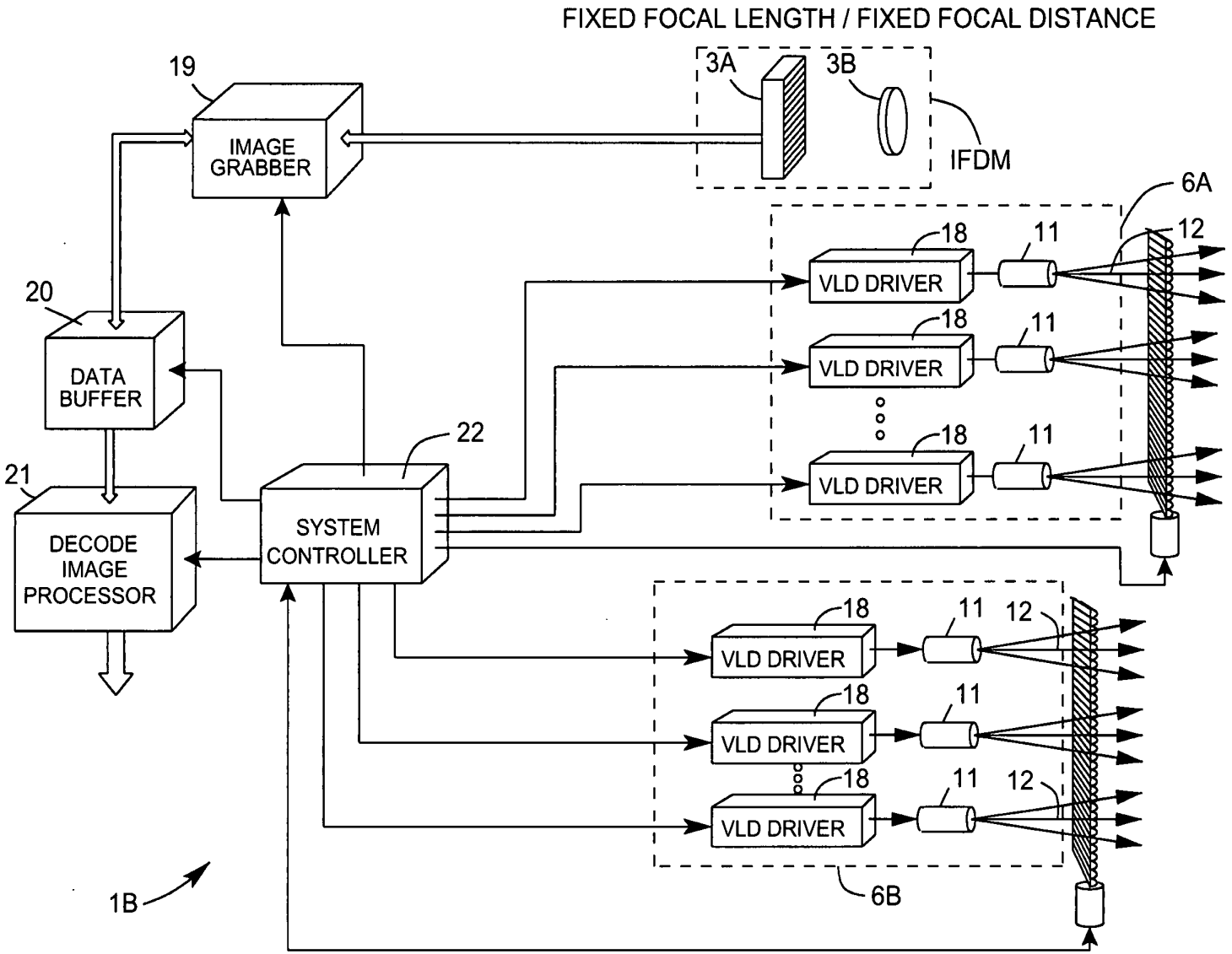

FIXED FOCAL LENGTH / FIXED FOCAL DISTANCE
19
IMAGE GRABBER
3A
3B
IFDM
6A
18
11
12
VLD DRIVER
VLD DRIVER
VLD DRIVER
20
DATA BUFFER
21
DECODE IMAGE PROCESSOR
22
SYSTEM CONTROLLER
VLD DRIVER
VLD DRIVER
VLD DRIVER
6B
1B

FIG. 1Q2

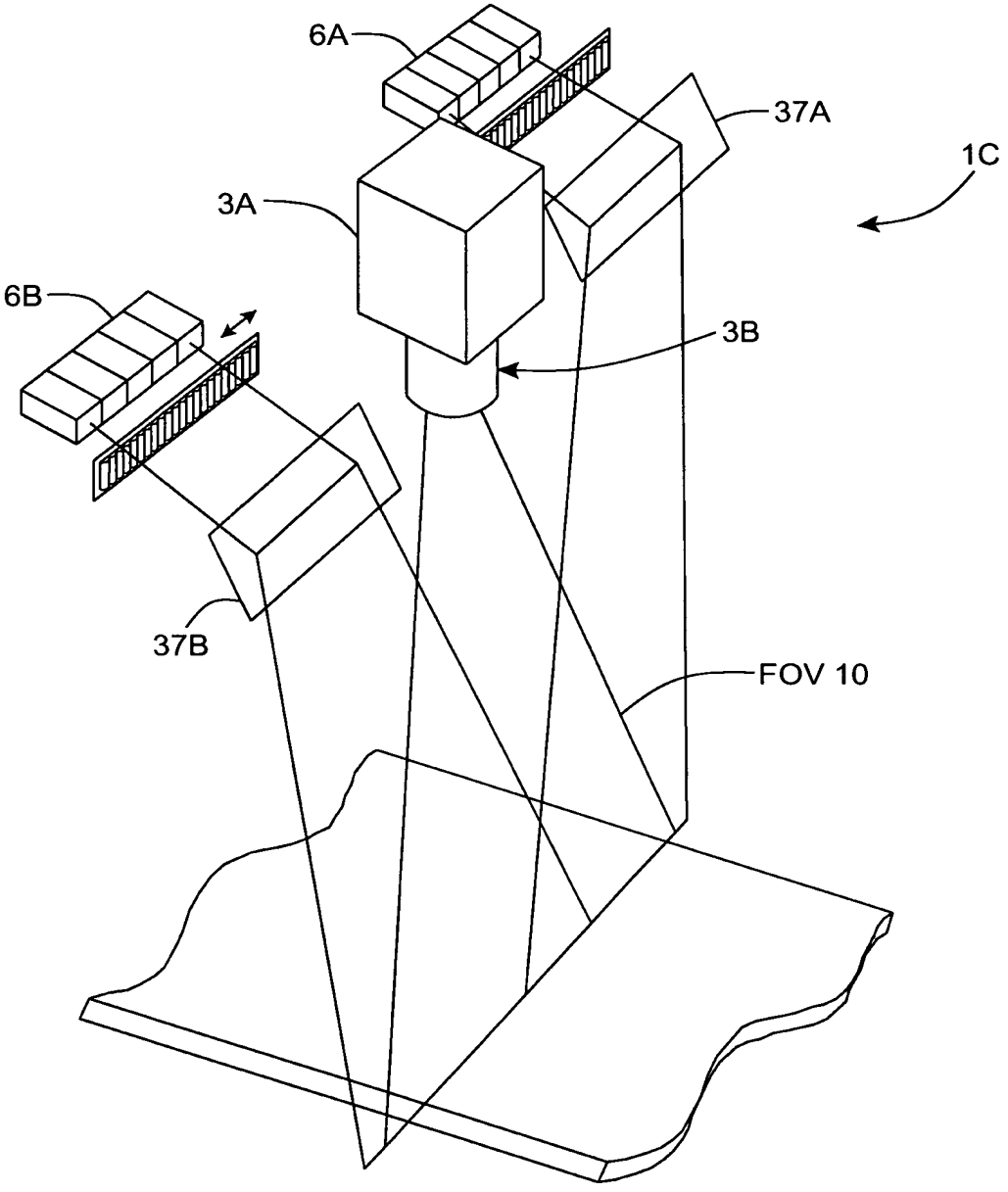


FIG. 1R1

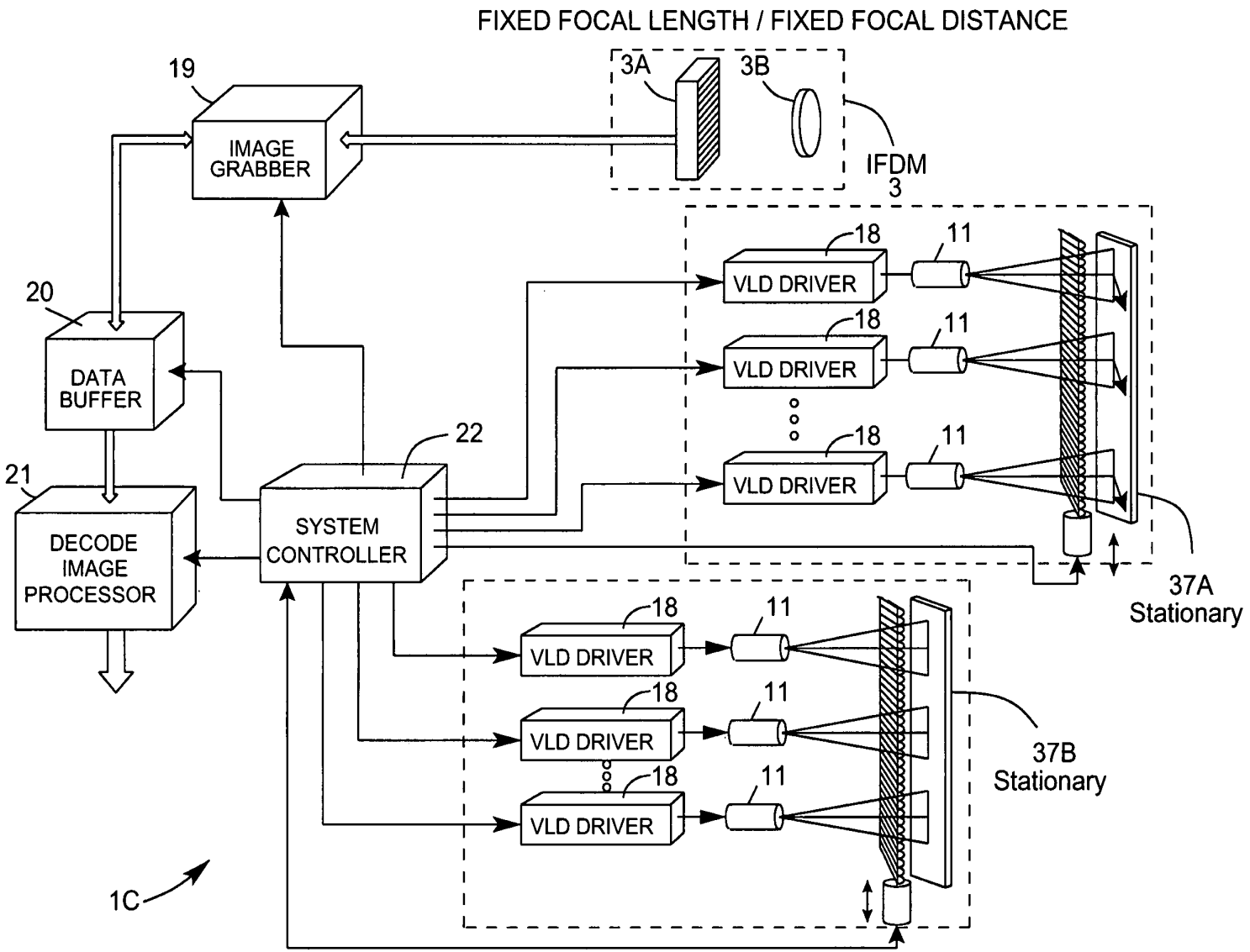

FIXED FOCAL LENGTH / FIXED FOCAL DISTANCE
19
IMAGE GRABBER
3A
3B
IFDM 3
20
DATA BUFFER
21
DECODE IMAGE PROCESSOR
22
SYSTEM CONTROLLER
18
11
VLD DRIVER
VLD DRIVER
VLD DRIVER
37A Stationary
VLD DRIVER
VLD DRIVER
VLD DRIVER
37B Stationary
1C

FIG. 1R2

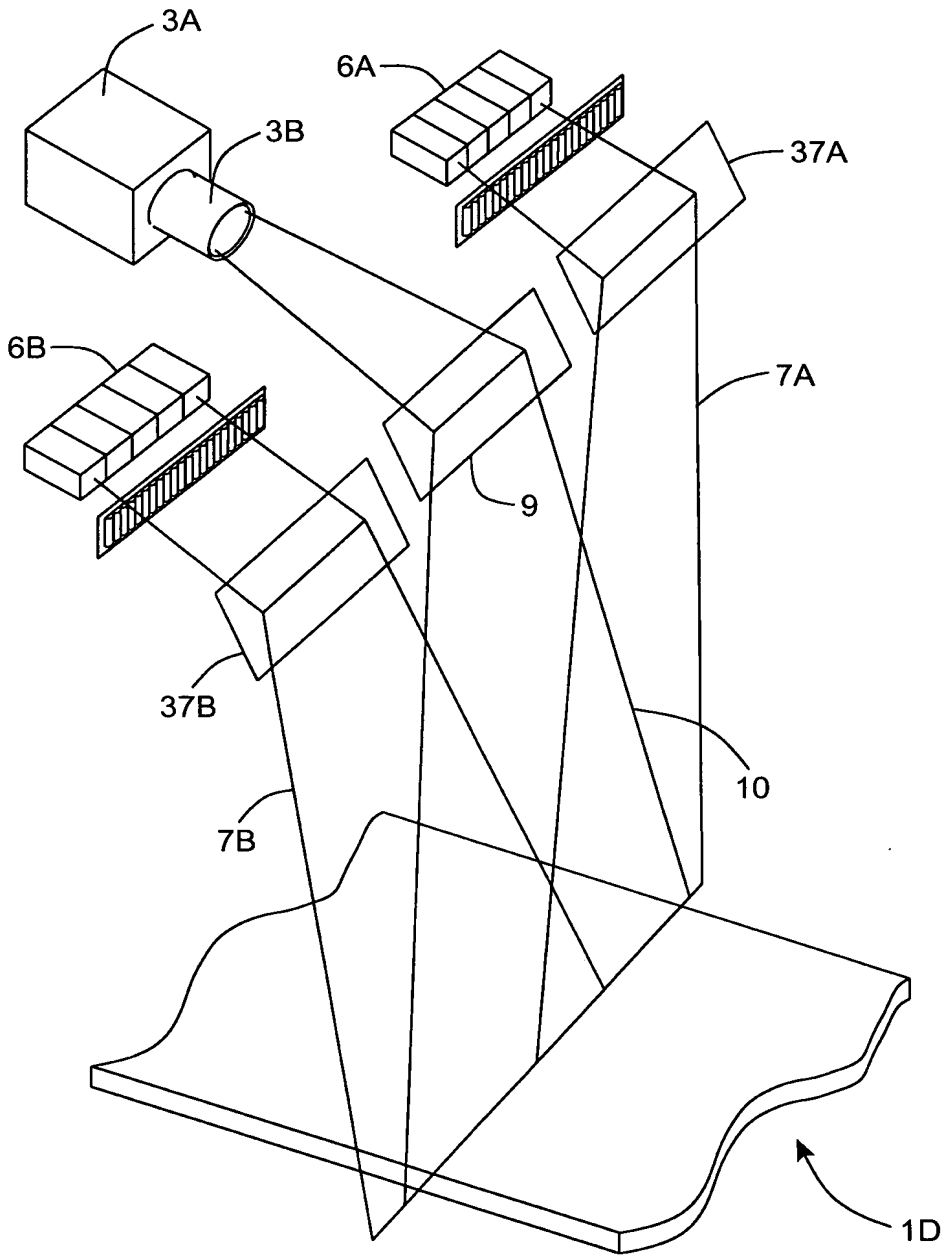


FIG. 1S1

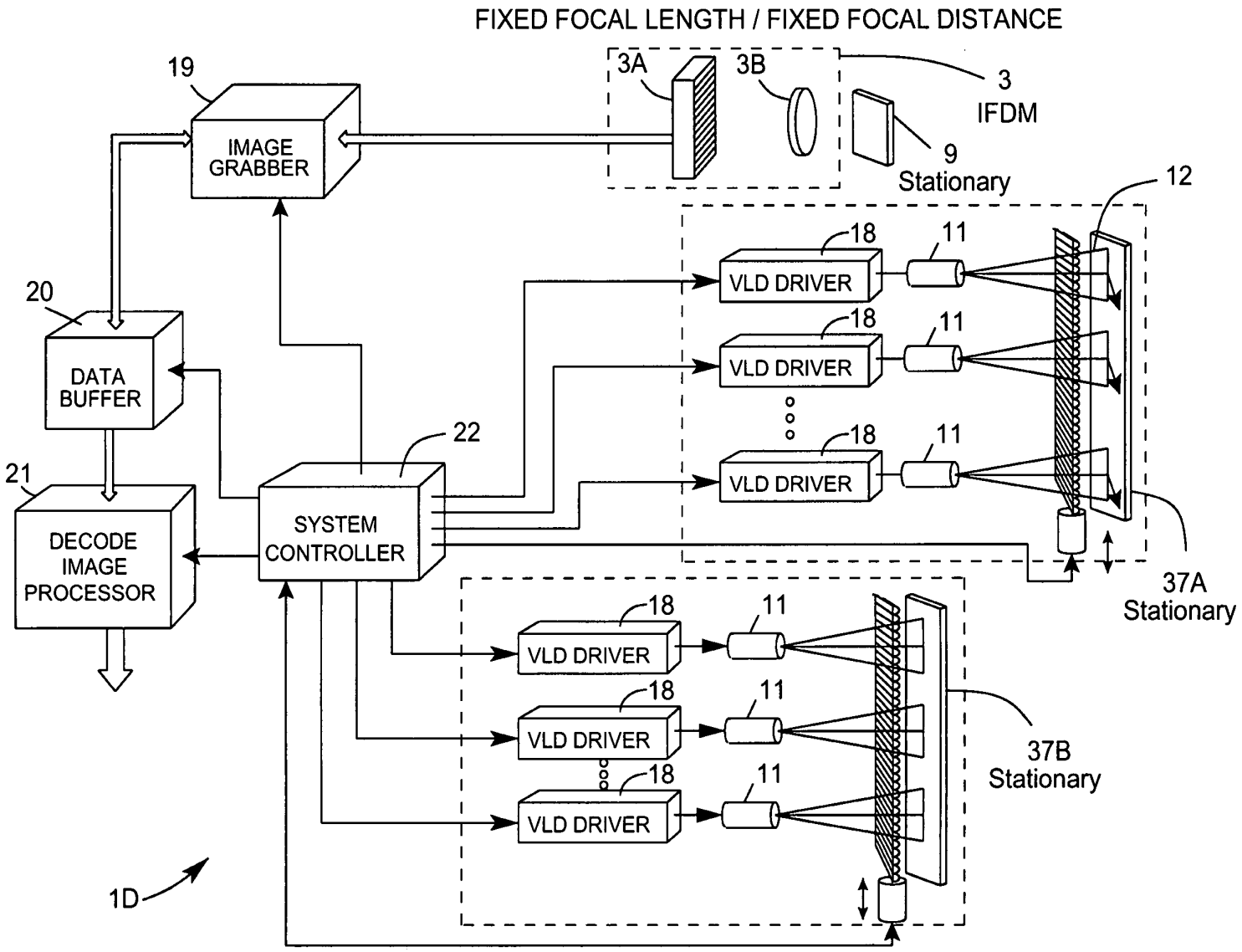

FIXED FOCAL LENGTH / FIXED FOCAL DISTANCE
19
IMAGE GRABBER
3A
3B
3
IFDM
9
Stationary
12
18
11
VLD DRIVER
20
DATA BUFFER
22
21
DECODE IMAGE PROCESSOR
SYSTEM CONTROLLER
37A
Stationary
37B
Stationary
1D

FIG. 1S2

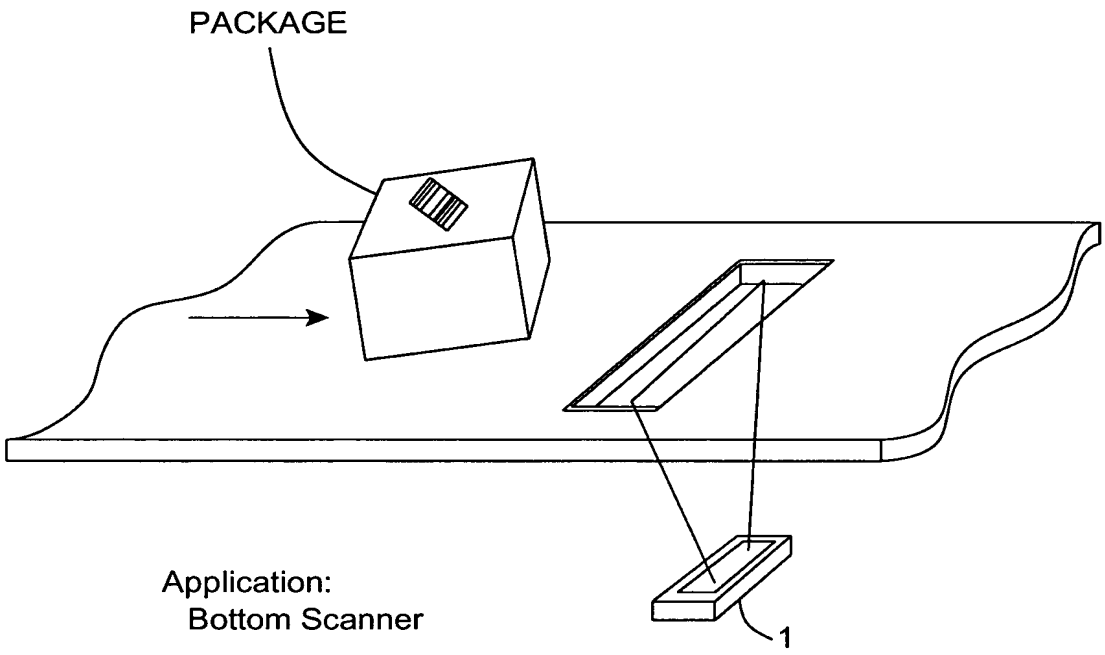


FIG. 1T

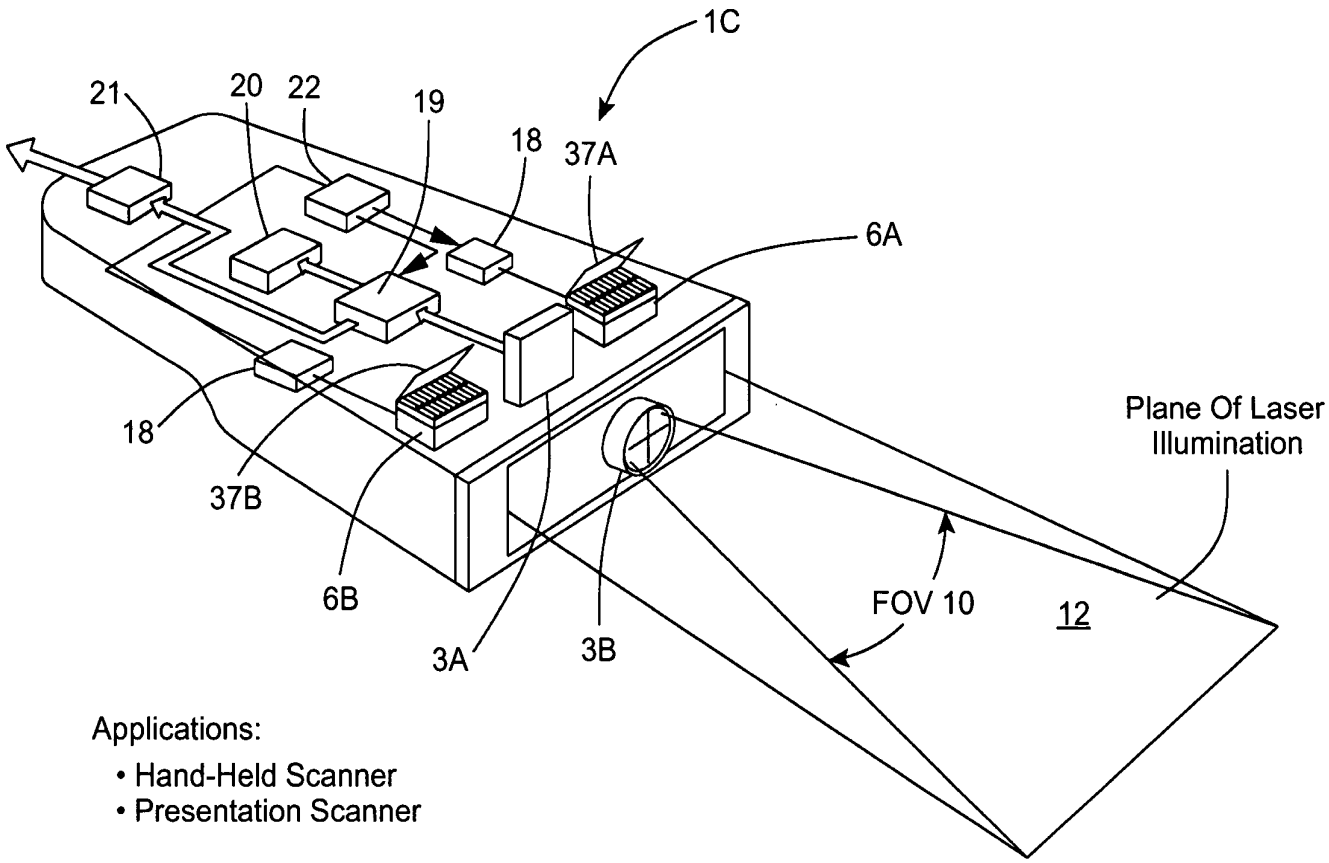

1C
21
20
22
19
18
37A
6A
18
37B
6B
3A
3B
Plane Of Laser Illumination
FOV 10
12
Applications:
• Hand-Held Scanner
• Presentation Scanner

FIG. 1U

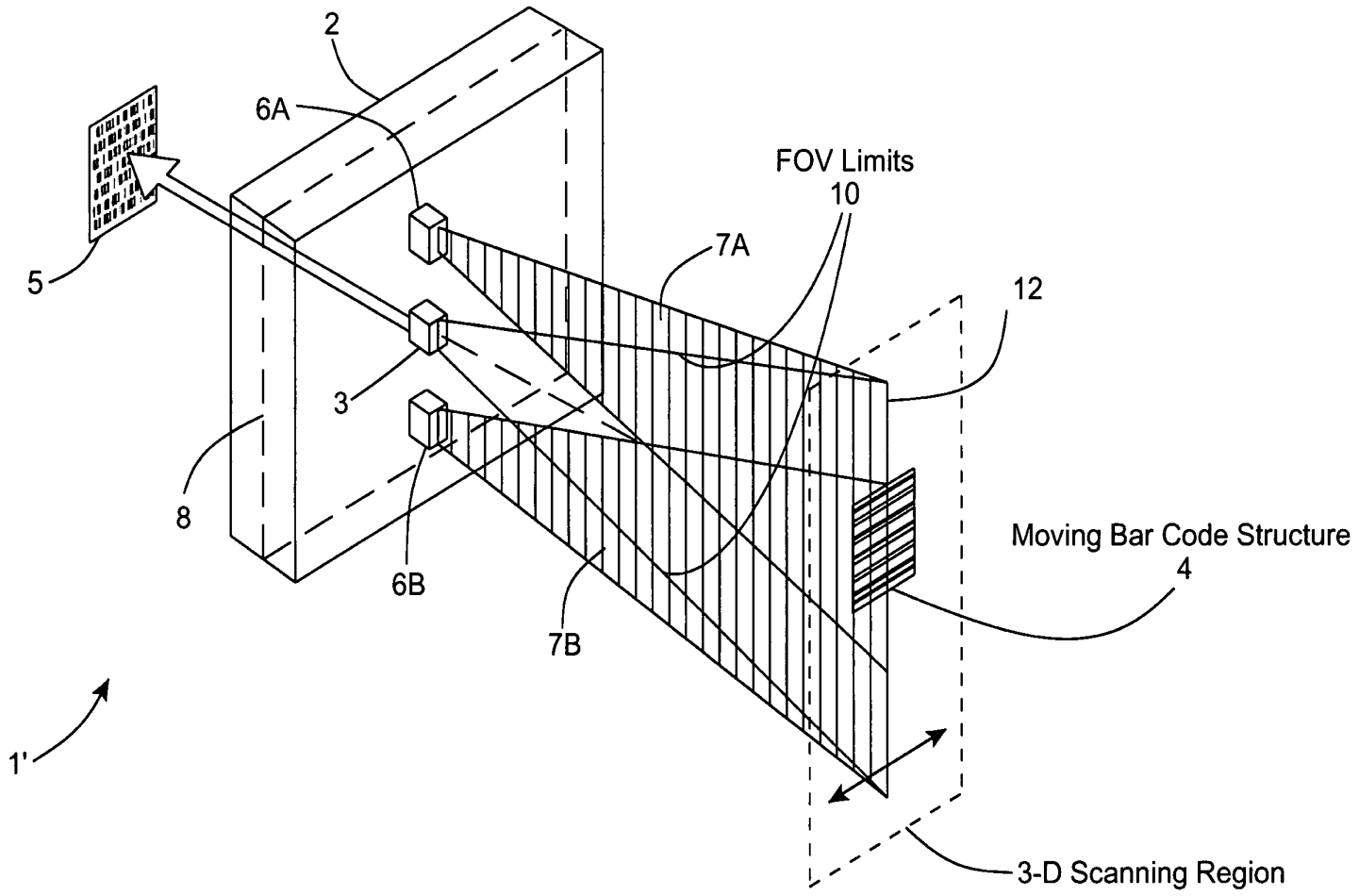

2
6A
FOV Limits
10
7A
12
5
3
8
6B
7B
Moving Bar Code Structure
4
1'
3-D Scanning Region

FIG. 1V1

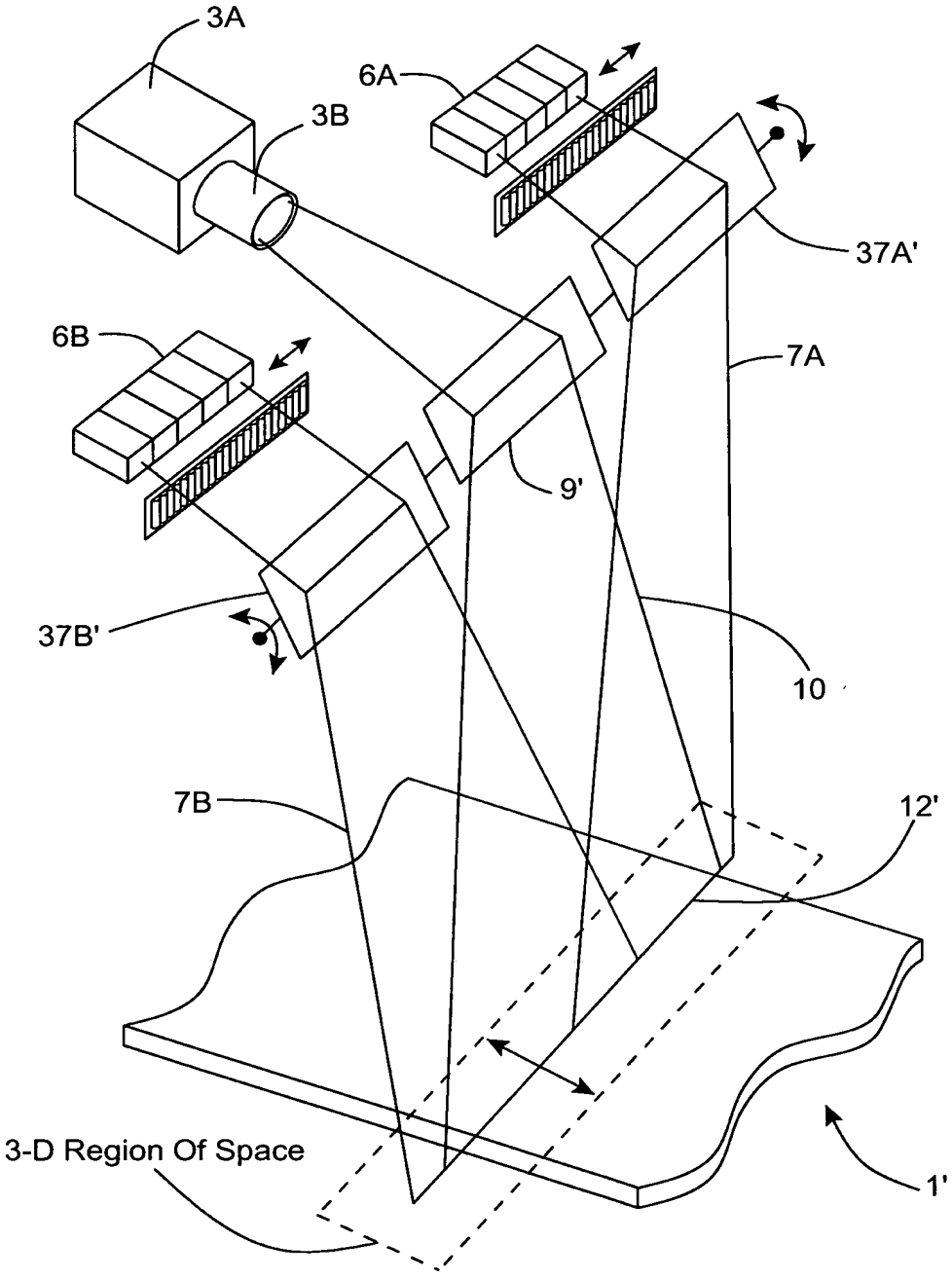


FIG. 1V2

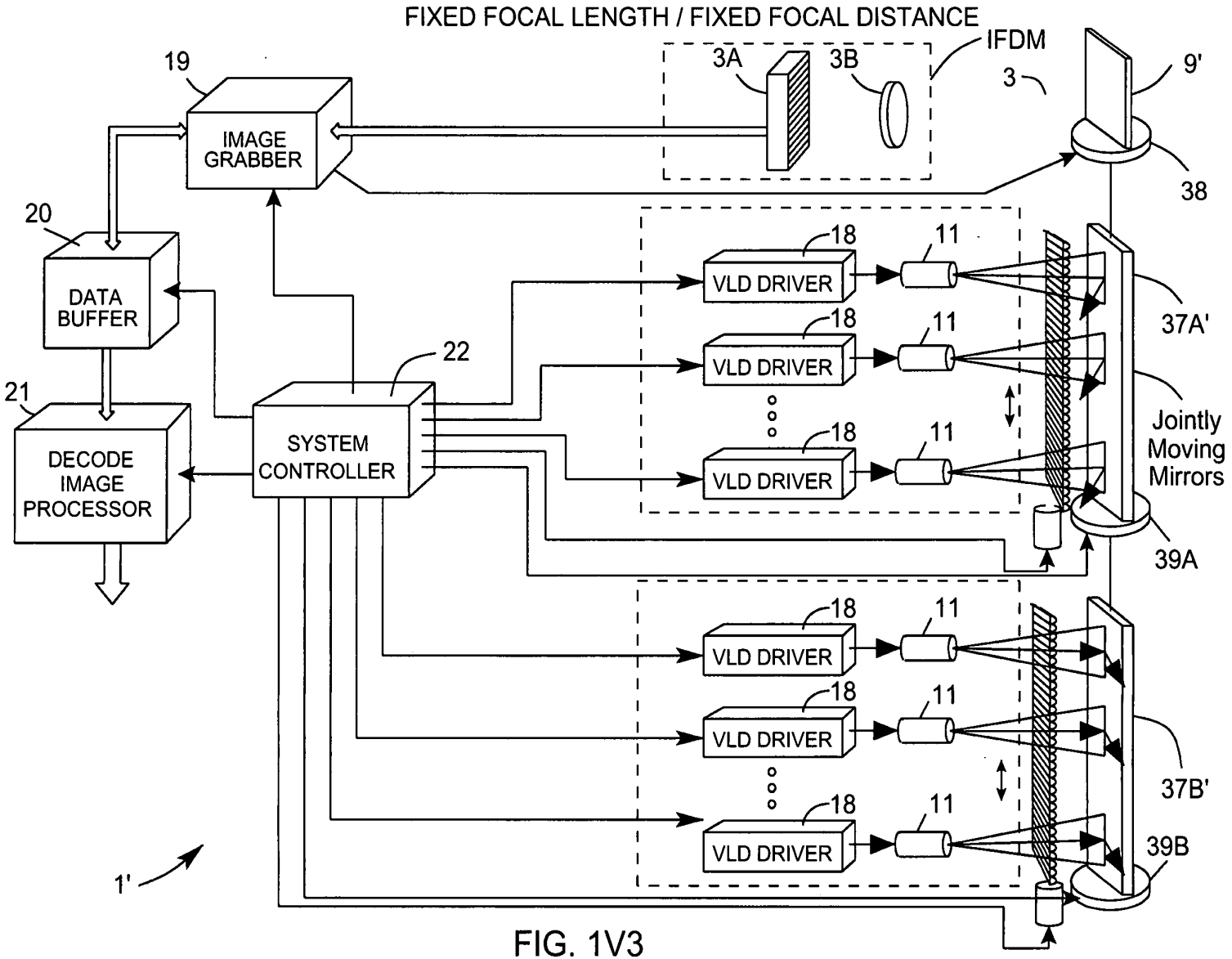

FIXED FOCAL LENGTH / FIXED FOCAL DISTANCE
IFDM
3
3A
3B
9'
38
19
IMAGE GRABBER
20
DATA BUFFER
21
DECODE IMAGE PROCESSOR
22
SYSTEM CONTROLLER
18
11
VLD DRIVER
37A'
Jointly Moving Mirrors
39A
37B'
39B
1'

FIG. 1V3

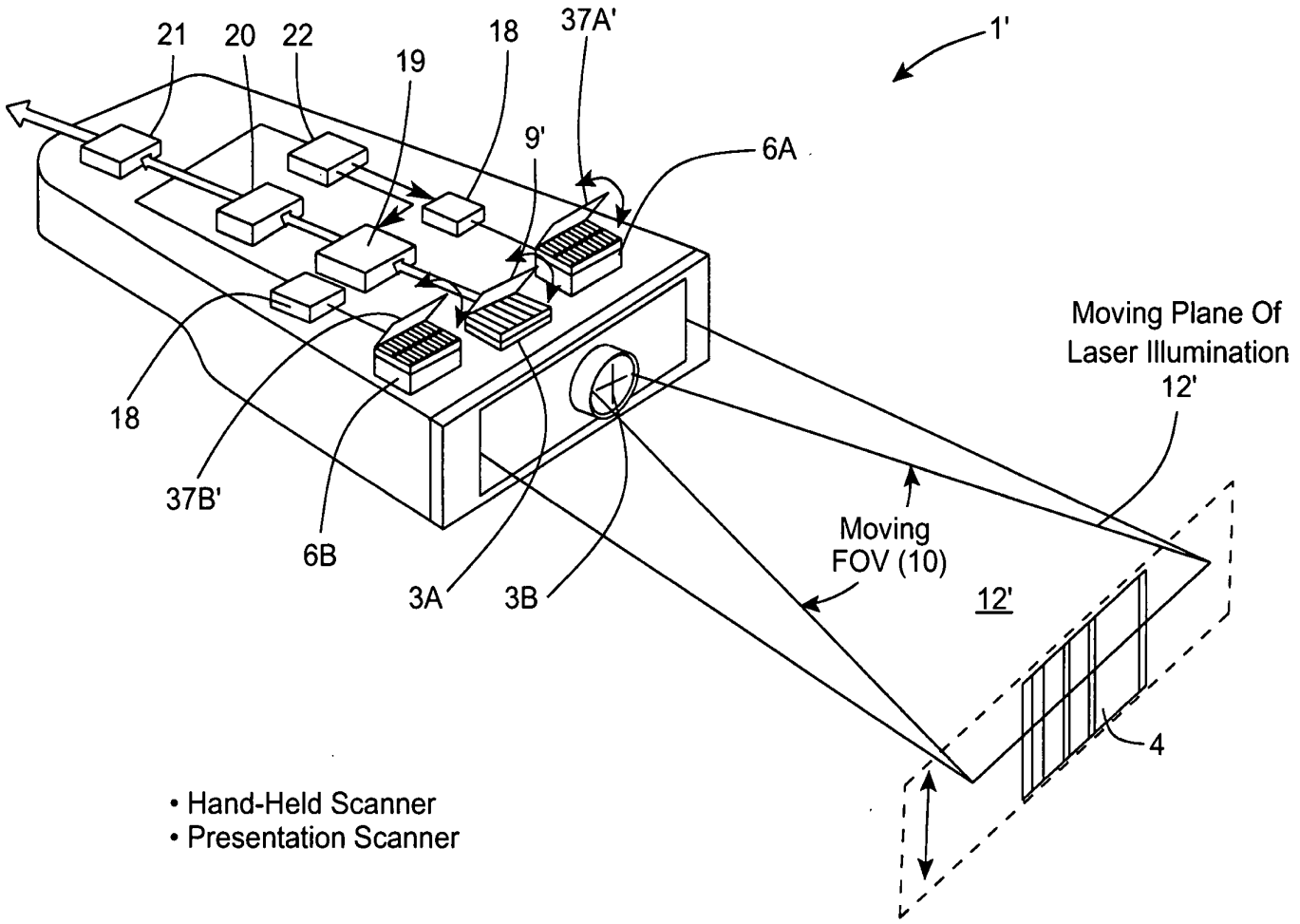
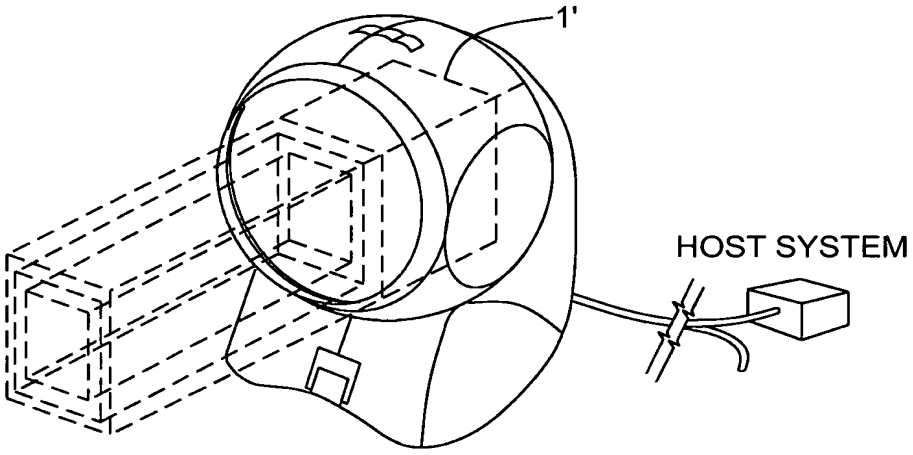

21
20
22
19
18
37A'
1'
9'
6A
Moving Plane Of
Laser Illumination
12'
18
37B'
6B
3A
3B
Moving
FOV (10)
12'
4
• Hand-Held Scanner
• Presentation Scanner

FIG. 1V4



PRESENTATION TYPE SCANNER

FIG. 1V5

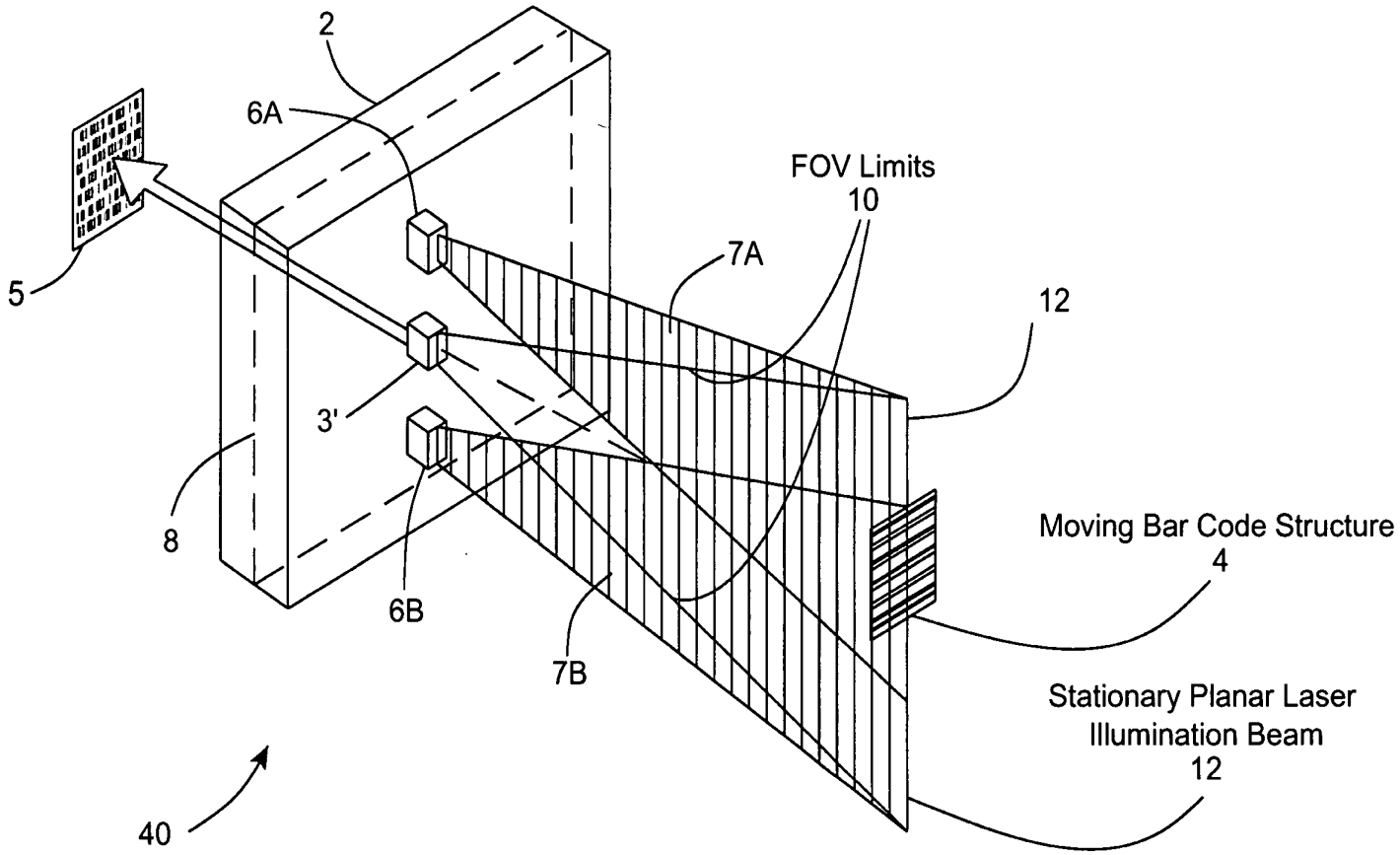

2
6A
FOV Limits
10
7A
12
5
3'
8
6B
7B
Moving Bar Code Structure
4
Stationary Planar Laser
Illumination Beam
12
40

FIG. 2A

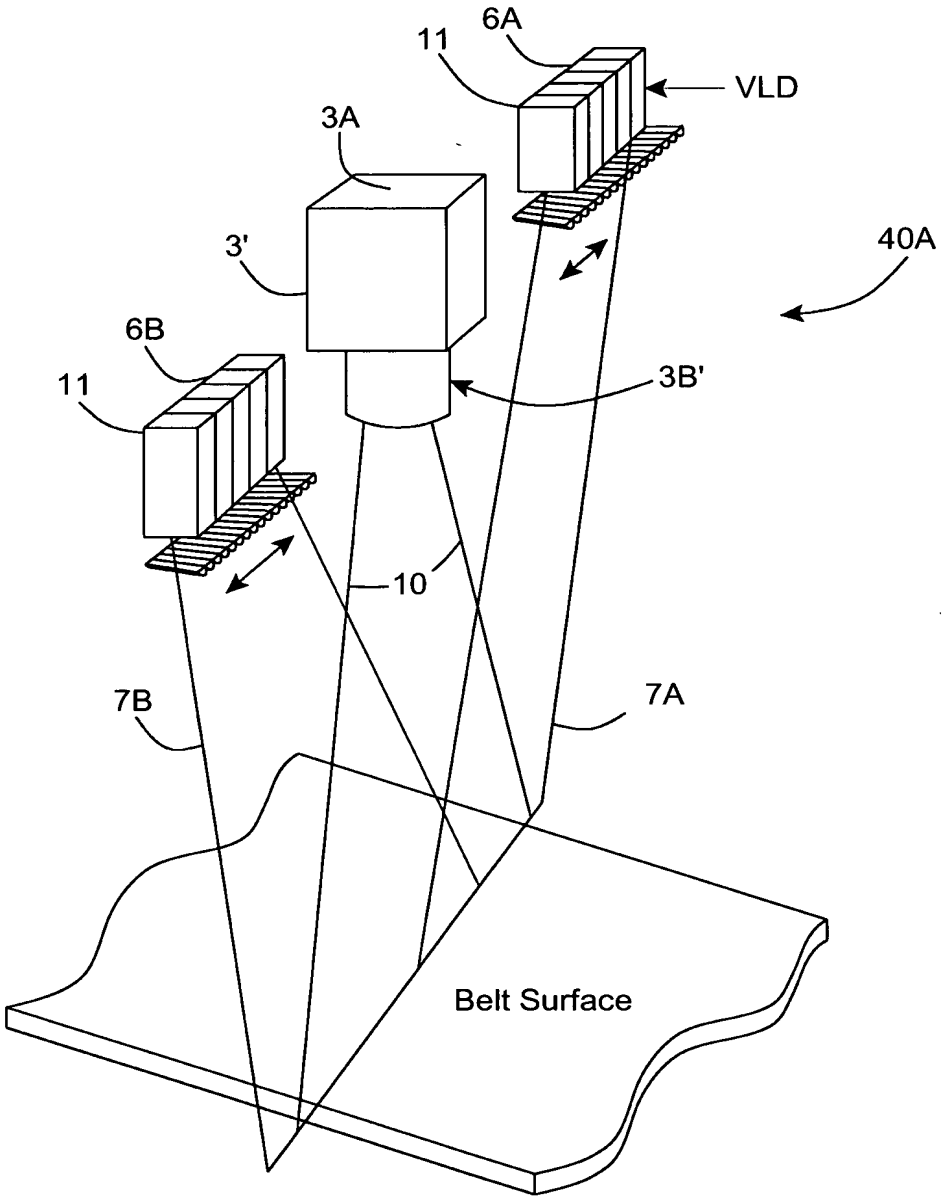


FIG. 2B1

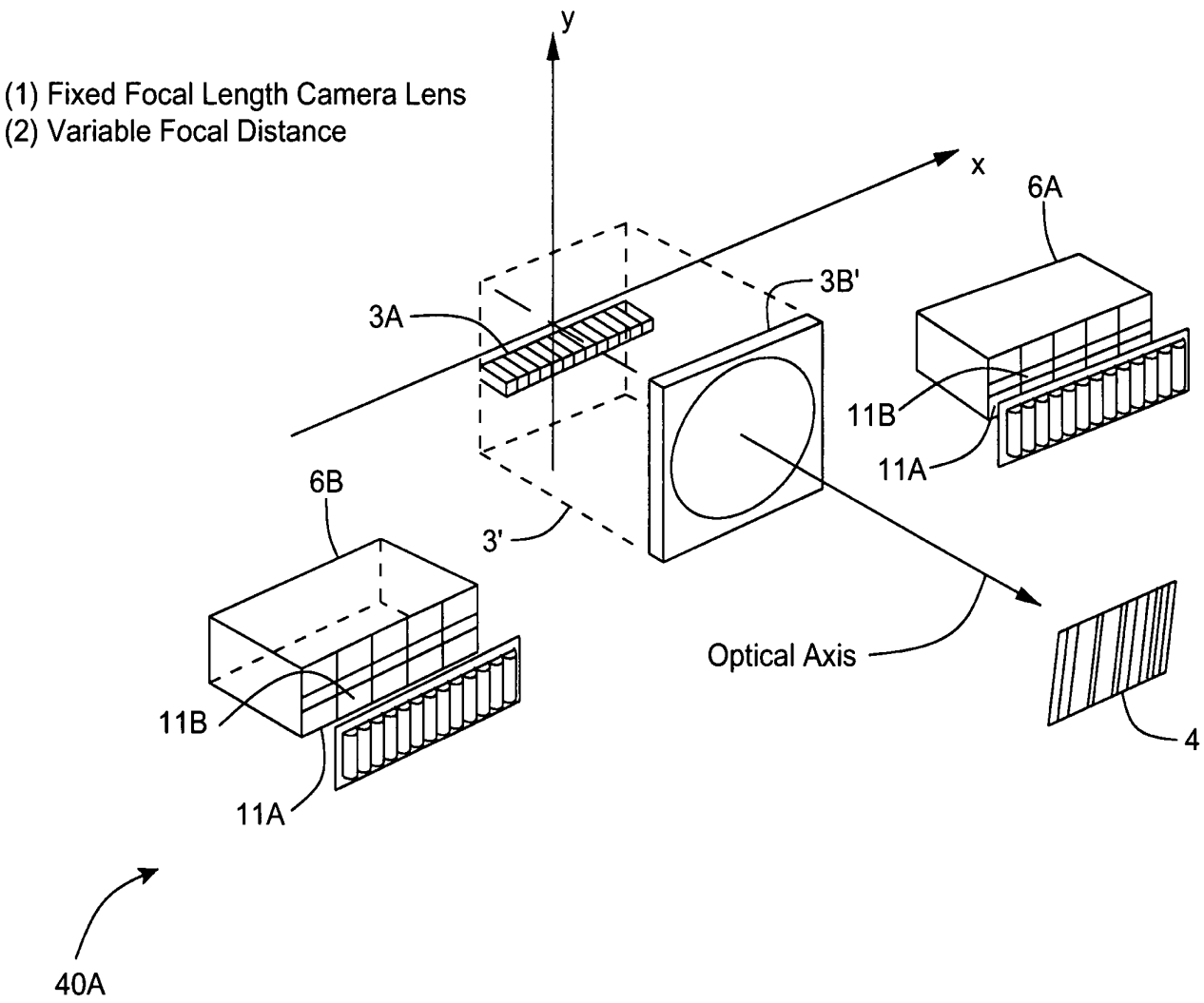

(1) Fixed Focal Length Camera Lens
(2) Variable Focal Distance
y
x
6A
3B'
3A
11B
11A
6B
3'
Optical Axis
11B
11A
4
40A

FIG. 2B2

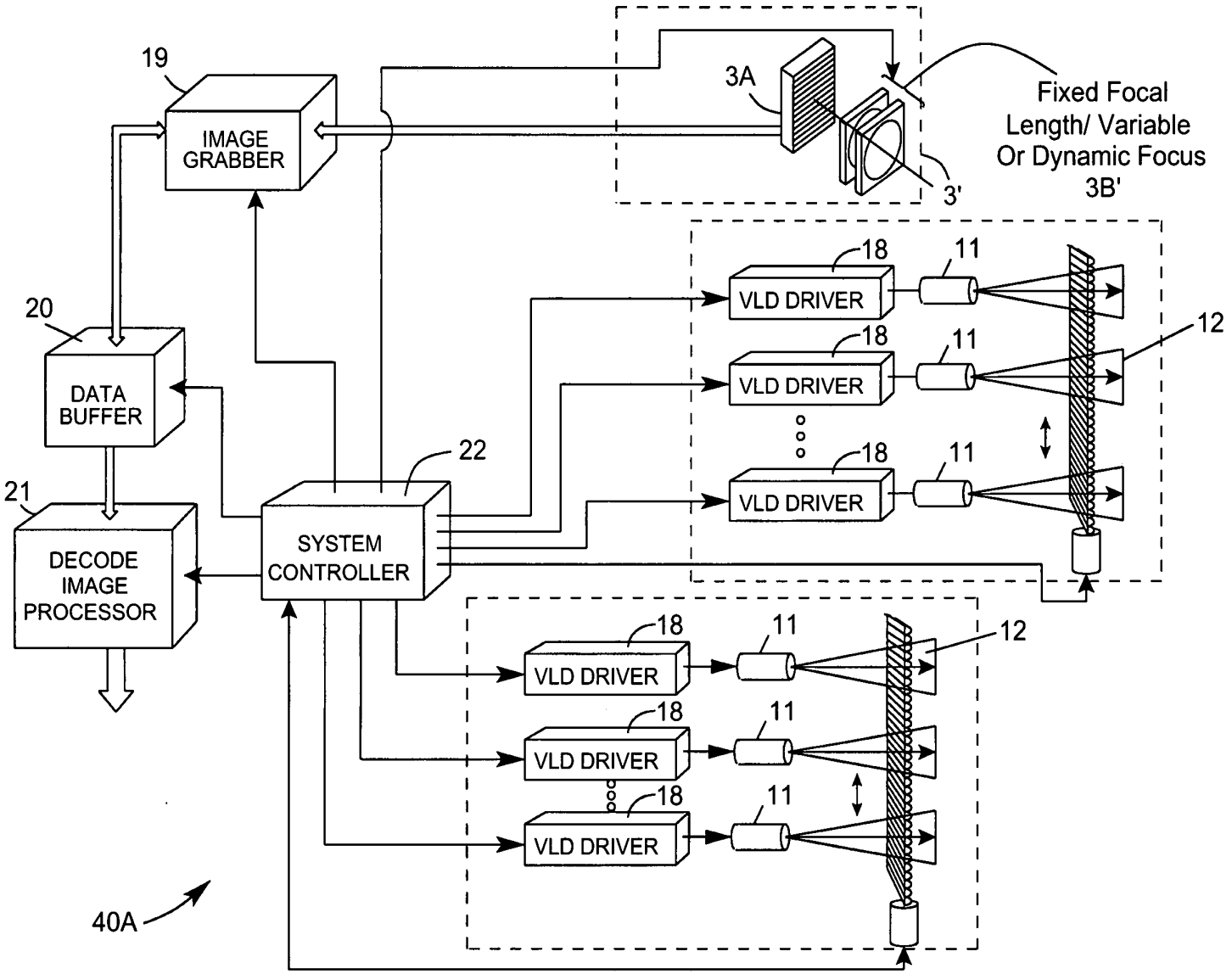

19
IMAGE GRABBER
3A
3'
Fixed Focal Length/ Variable Or Dynamic Focus
3B'
20
DATA BUFFER
21
DECODE IMAGE PROCESSOR
22
SYSTEM CONTROLLER
18
11
VLD DRIVER
12
40A

FIG. 2C1

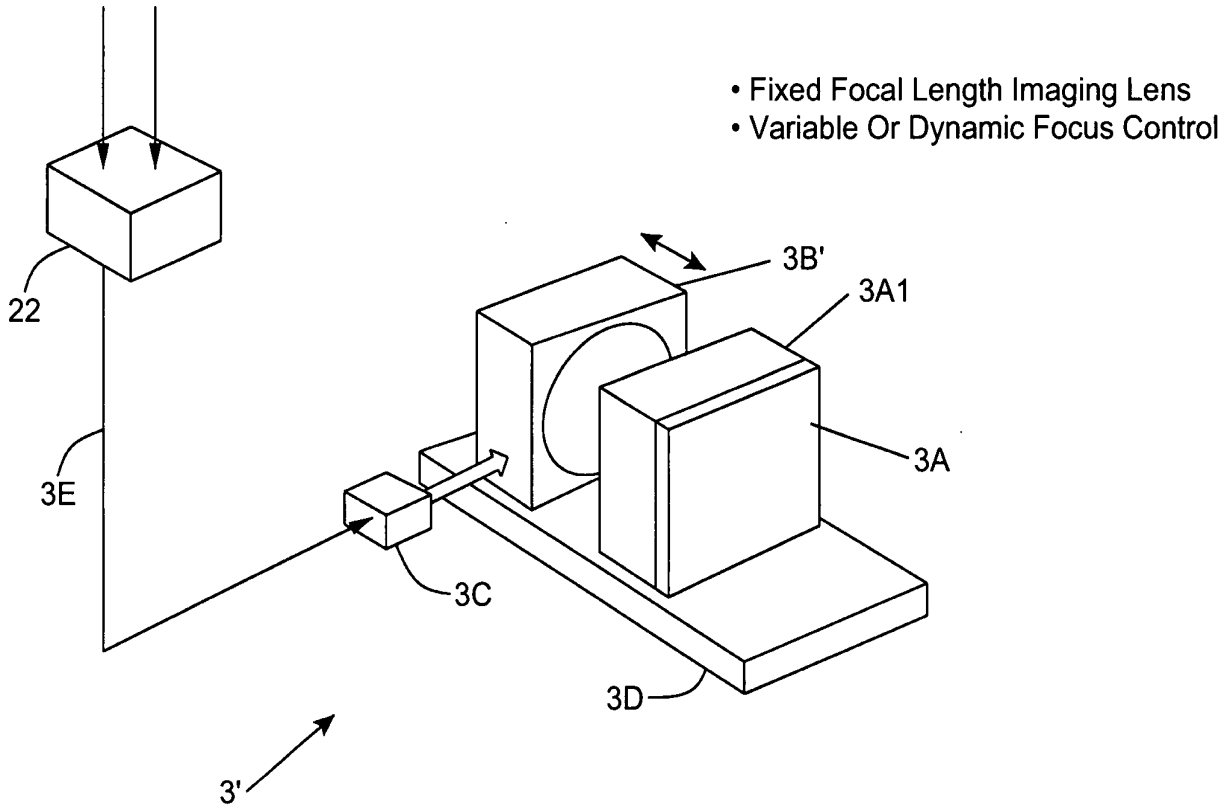

• Fixed Focal Length Imaging Lens
• Variable Or Dynamic Focus Control
22
3E
3B'
3A1
3A
3C
3D
3'

FIG. 2C2

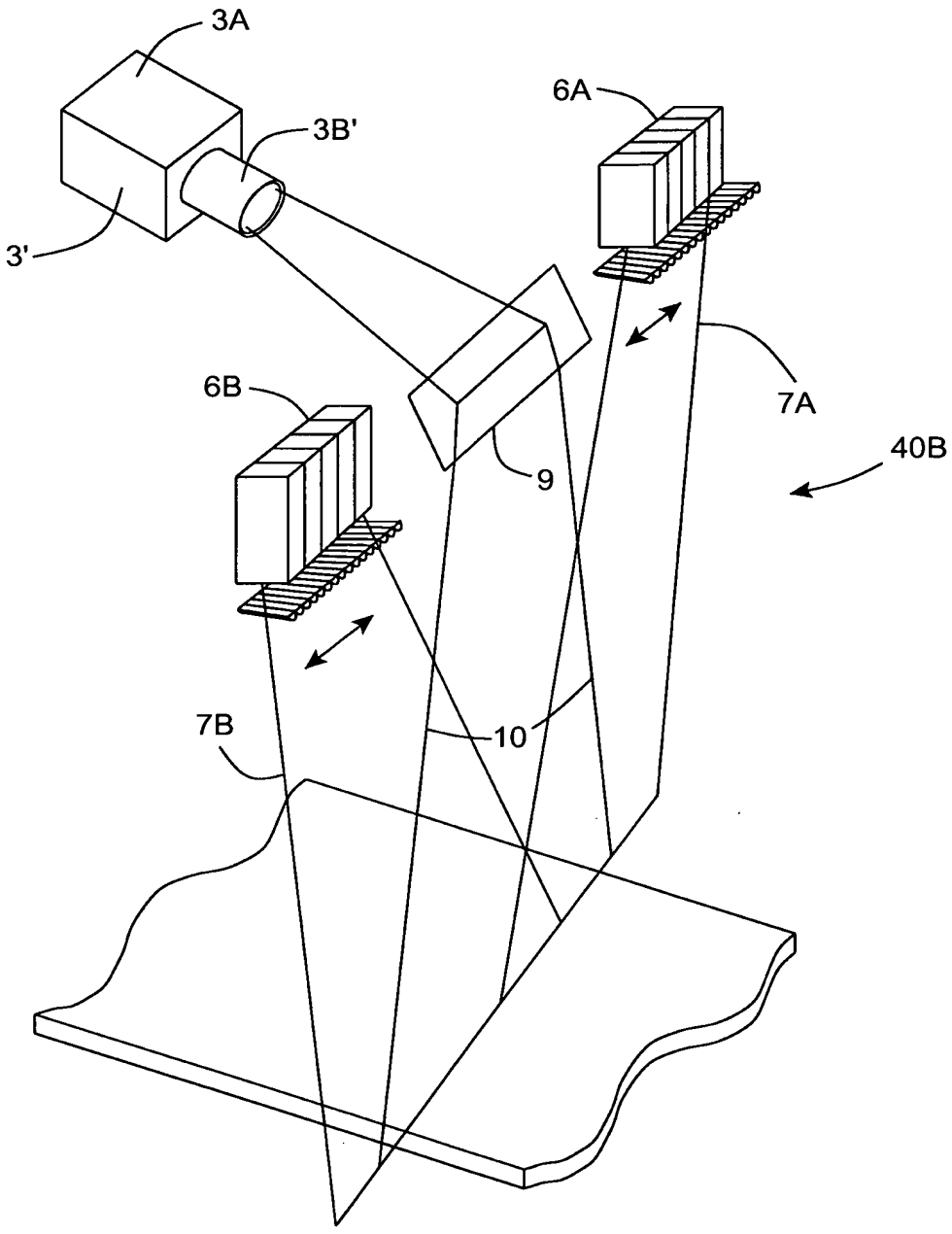


FIG. 2D1

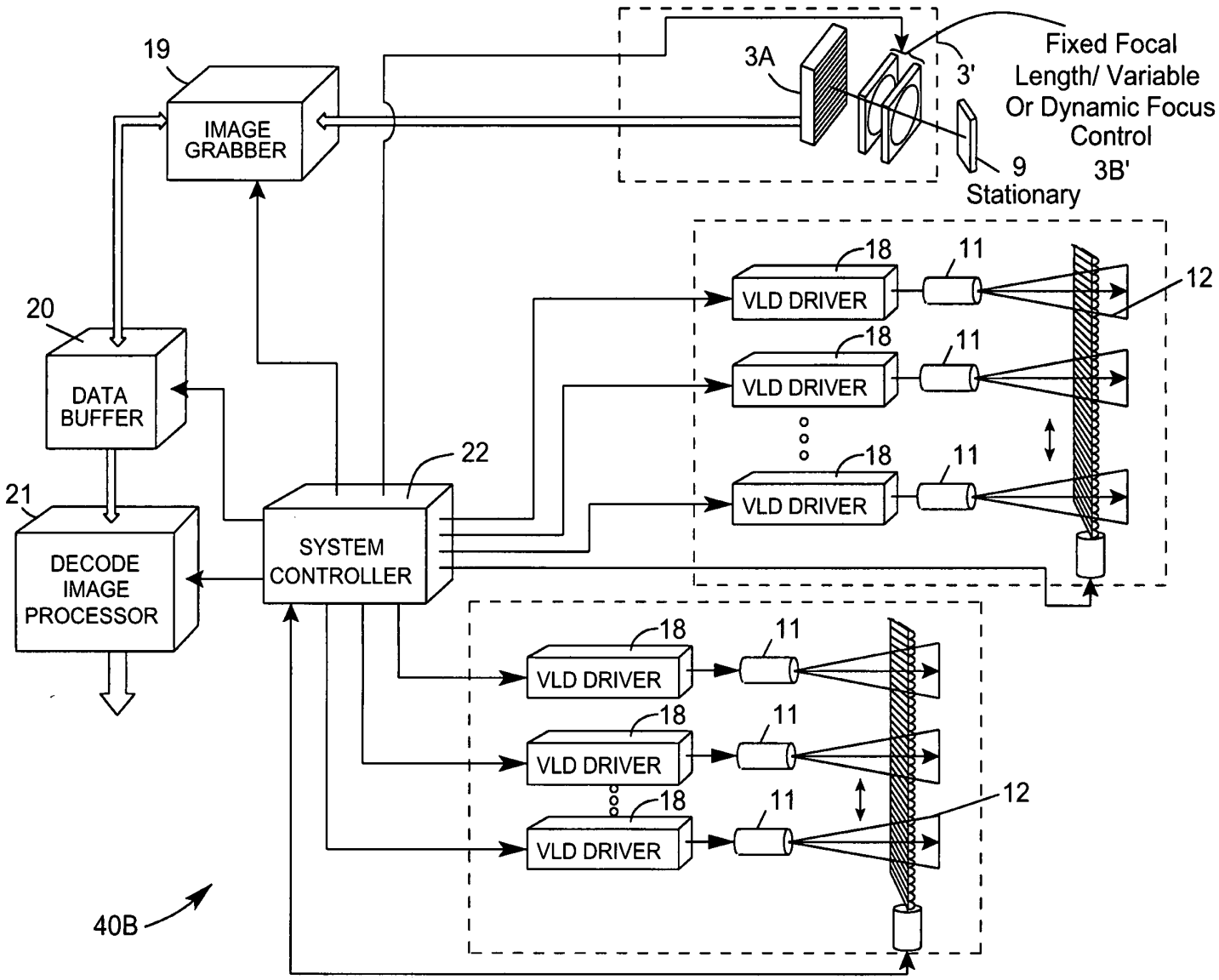

19
IMAGE GRABBER
3A
3'
Fixed Focal Length/ Variable Or Dynamic Focus Control
9
3B'
Stationary
18
11
12
VLD DRIVER
20
DATA BUFFER
22
21
DECODE IMAGE PROCESSOR
SYSTEM CONTROLLER
40B

FIG. 2D2

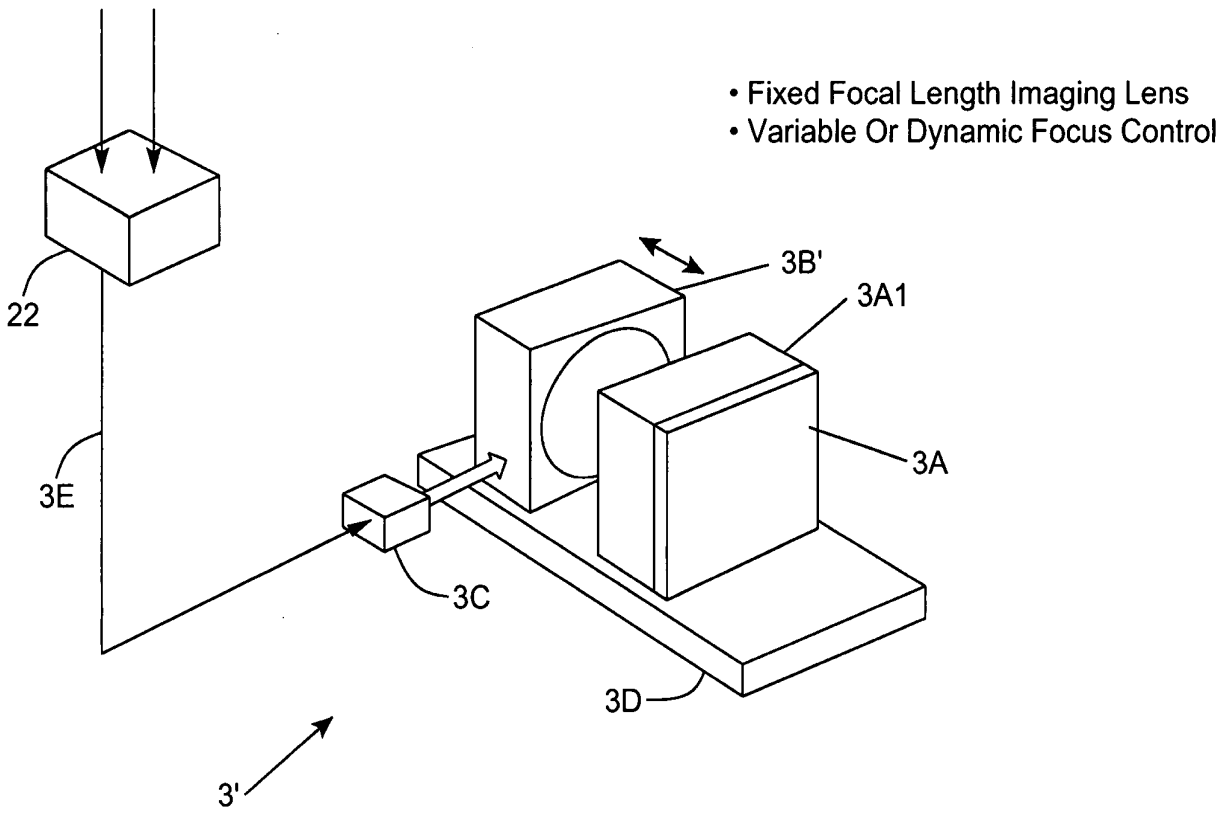

• Fixed Focal Length Imaging Lens
• Variable Or Dynamic Focus Control
22
3E
3B'
3A1
3A
3C
3D
3'

FIG. 2D3

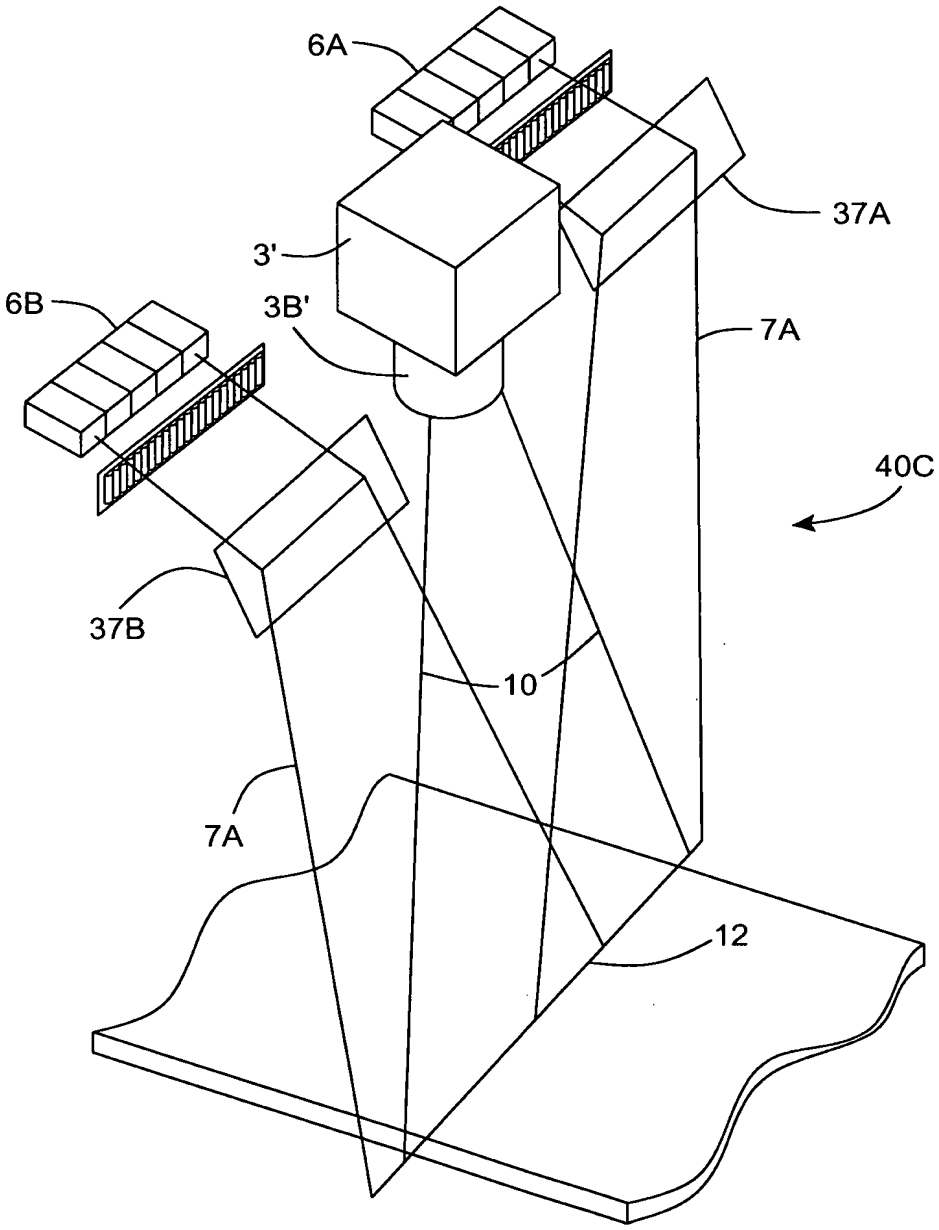


FIG. 2E1

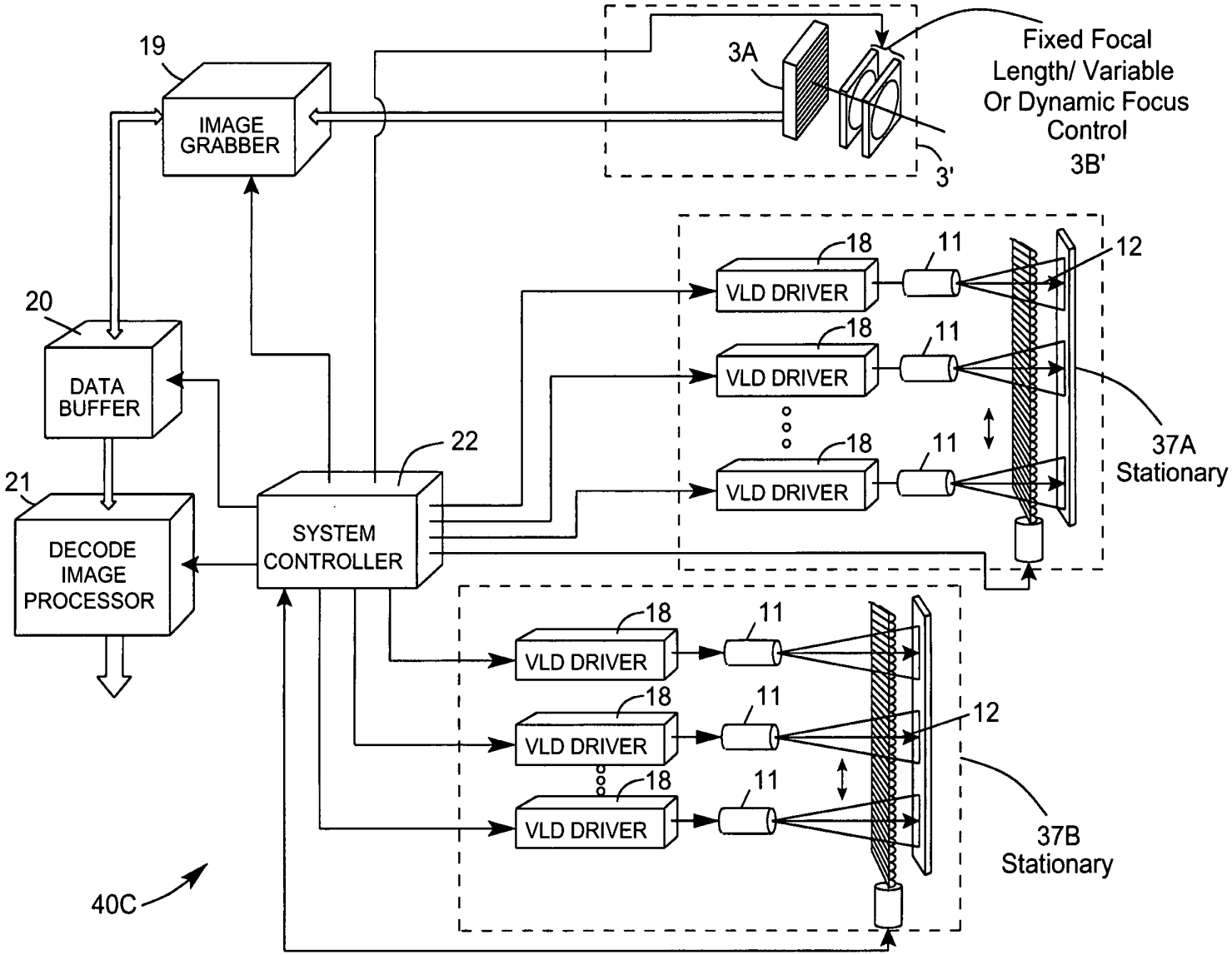

19
IMAGE GRABBER
3A
Fixed Focal Length/ Variable Or Dynamic Focus Control
3B'
3'
20
DATA BUFFER
21
DECODE IMAGE PROCESSOR
22
SYSTEM CONTROLLER
18
11
12
VLD DRIVER
VLD DRIVER
VLD DRIVER
37A Stationary
VLD DRIVER
VLD DRIVER
VLD DRIVER
37B Stationary
40C

FIG. 2E2

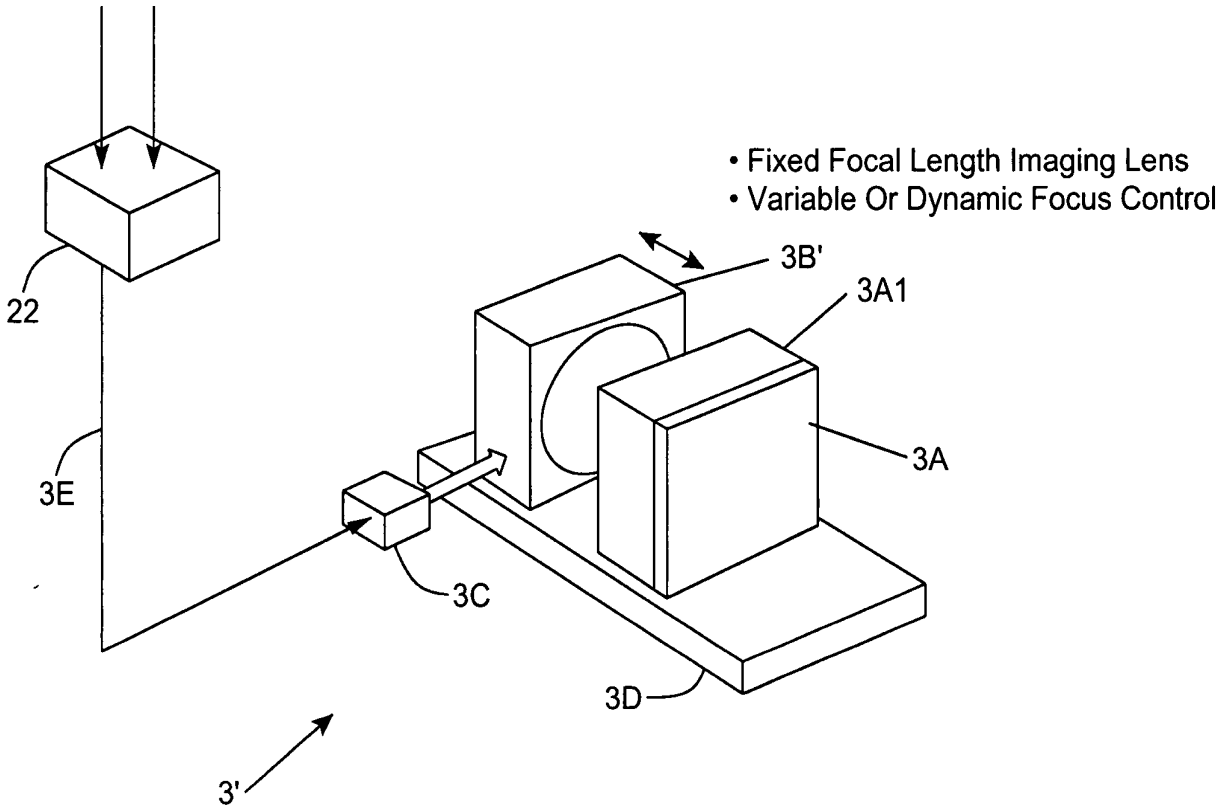

• Fixed Focal Length Imaging Lens
• Variable Or Dynamic Focus Control
22
3E
3B'
3A1
3A
3C
3D
3'

FIG. 2E3

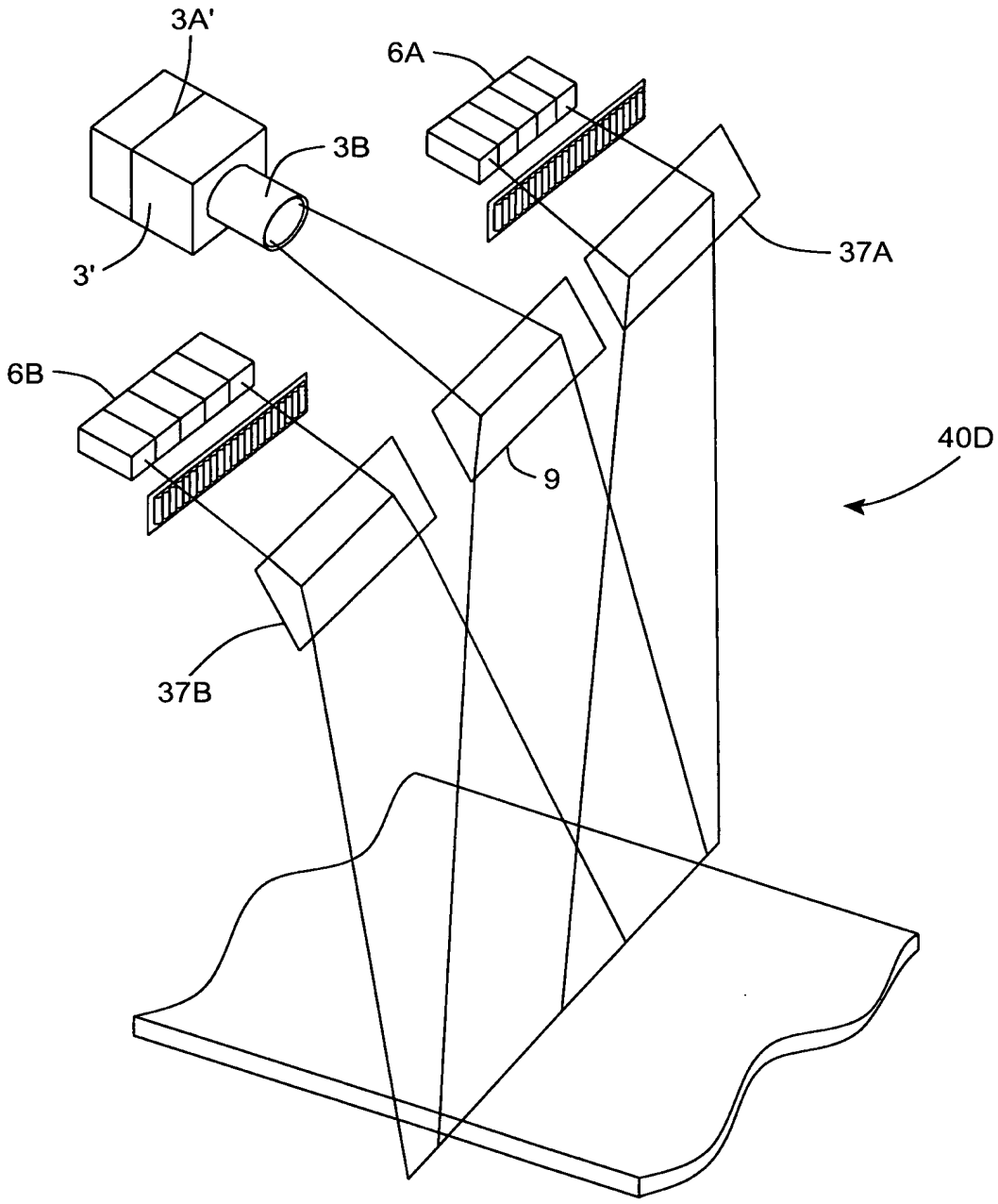


FIG. 2F1

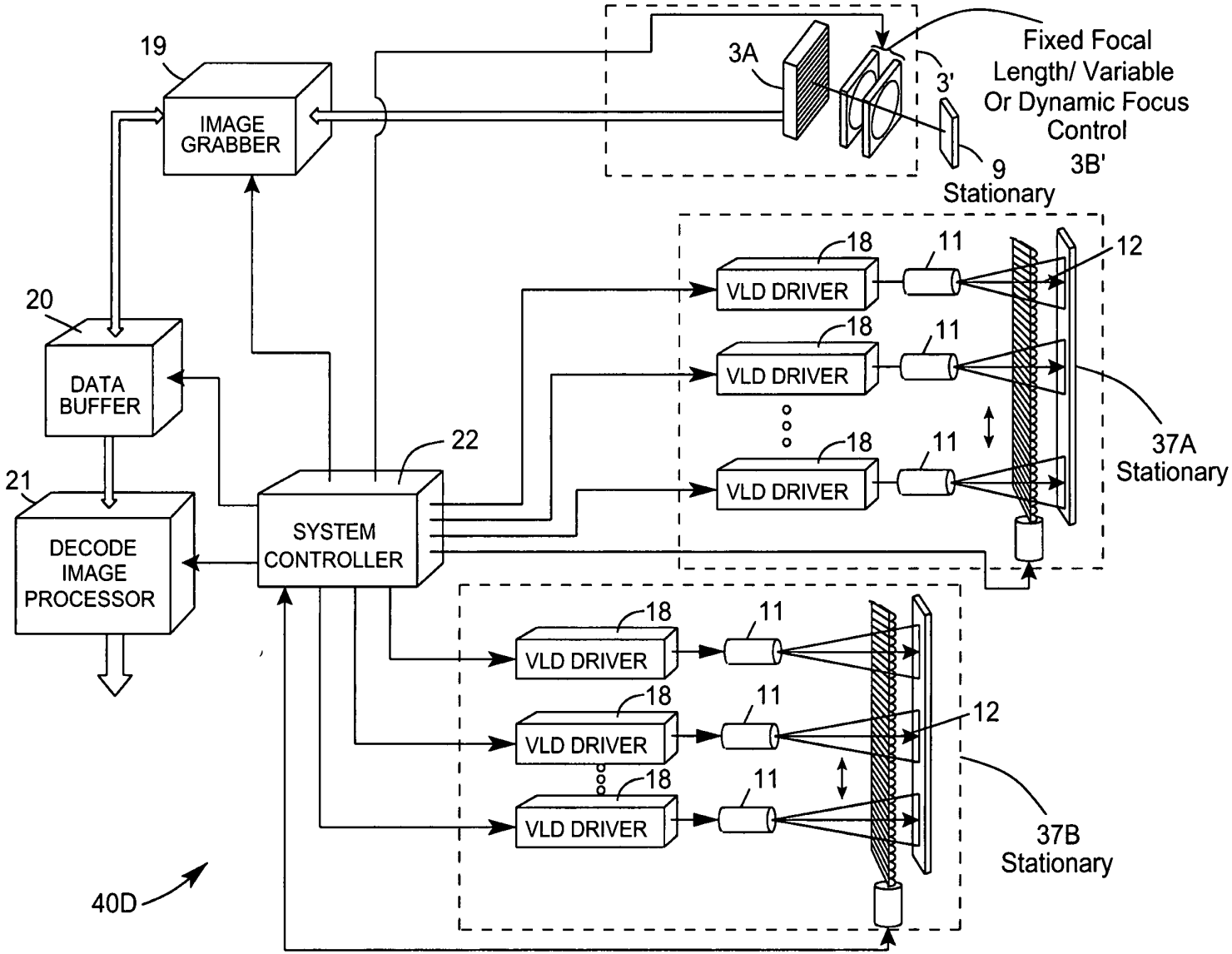

19
IMAGE GRABBER
3A
3'
Fixed Focal Length/ Variable Or Dynamic Focus Control
3B'
9
Stationary
20
DATA BUFFER
21
DECODE IMAGE PROCESSOR
22
SYSTEM CONTROLLER
18
11
VLD DRIVER
12
37A
Stationary
37B
Stationary
40D

FIG. 2F2

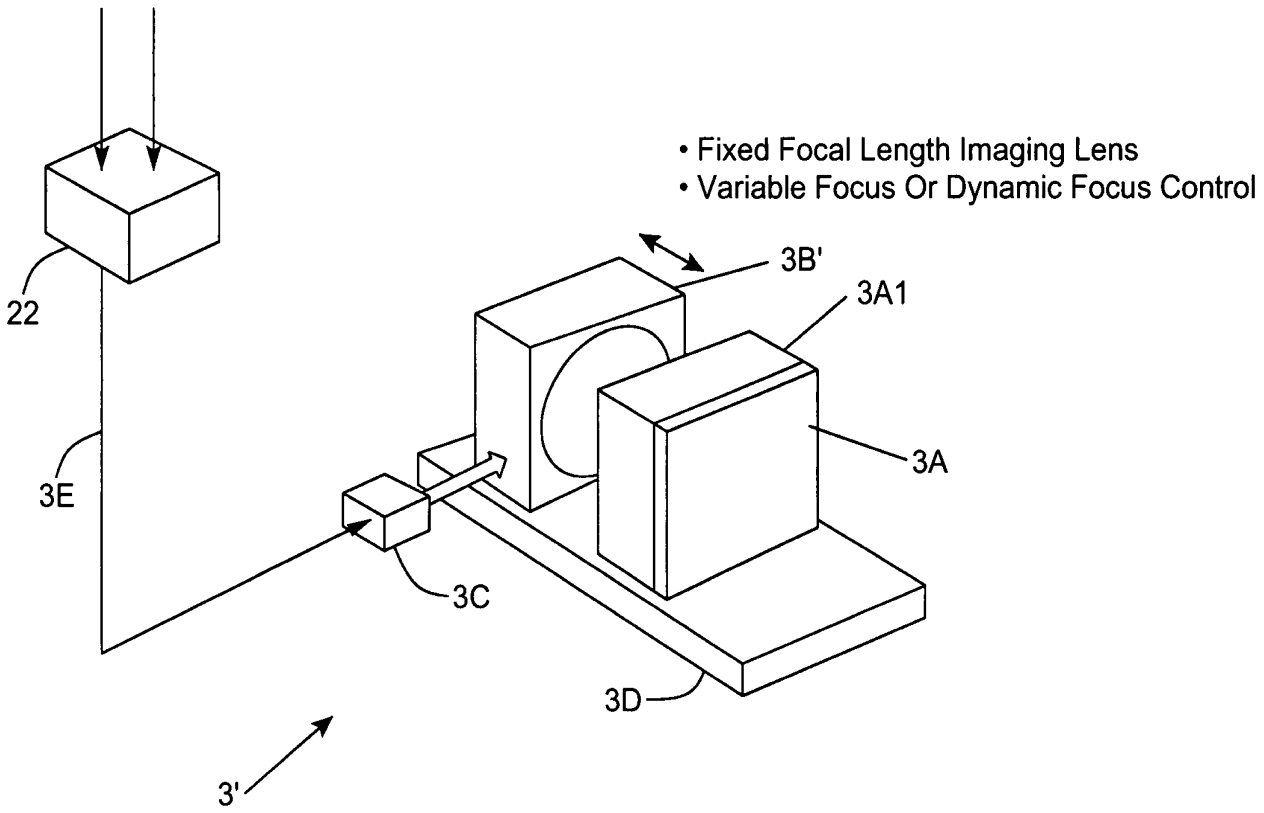

• Fixed Focal Length Imaging Lens
• Variable Focus Or Dynamic Focus Control
22
3E
3B'
3A1
3A
3C
3D
3'

FIG. 2F3

Top Conveyor Scanner:

- Fixed Focal Length Imaging Lens
- Variable Focal Distance Control

Side Conveyor Scanner:

- Fixed Focal Length Imaging Lens
- Dynamic Focal Distance Control

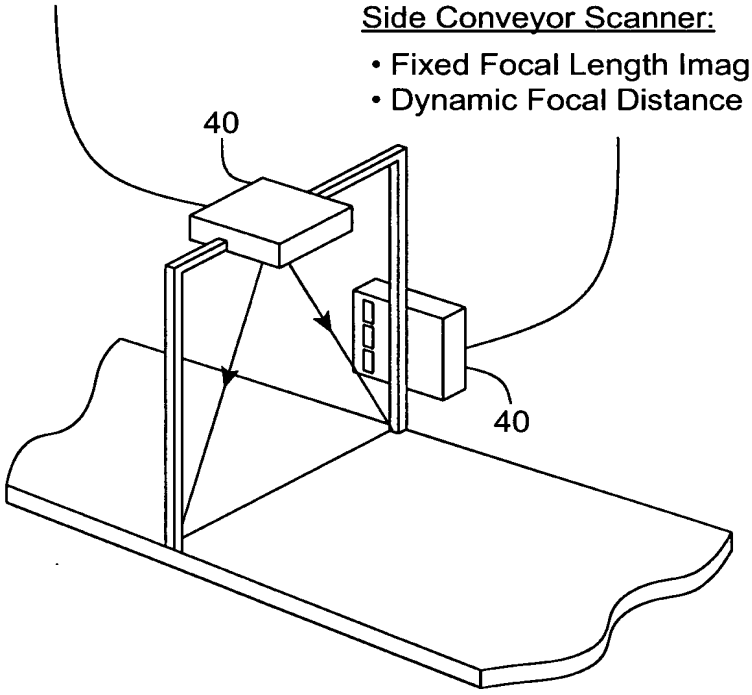


FIG. 2G

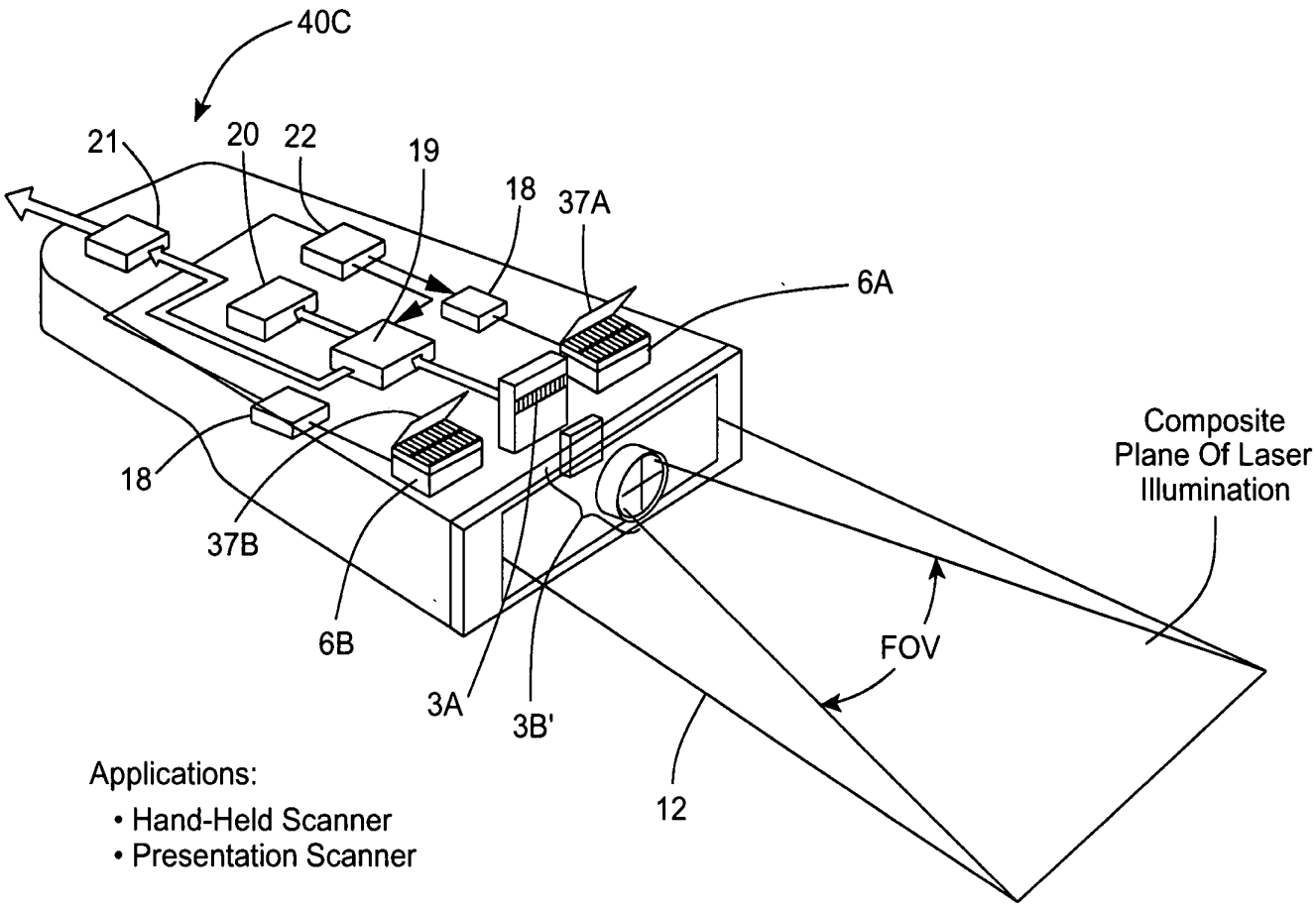

40C
21
20
22
19
18
37A
6A
18
37B
6B
3A
3B'
12
Composite
Plane Of Laser
Illumination
FOV
Applications:
• Hand-Held Scanner
• Presentation Scanner

FIG. 2H

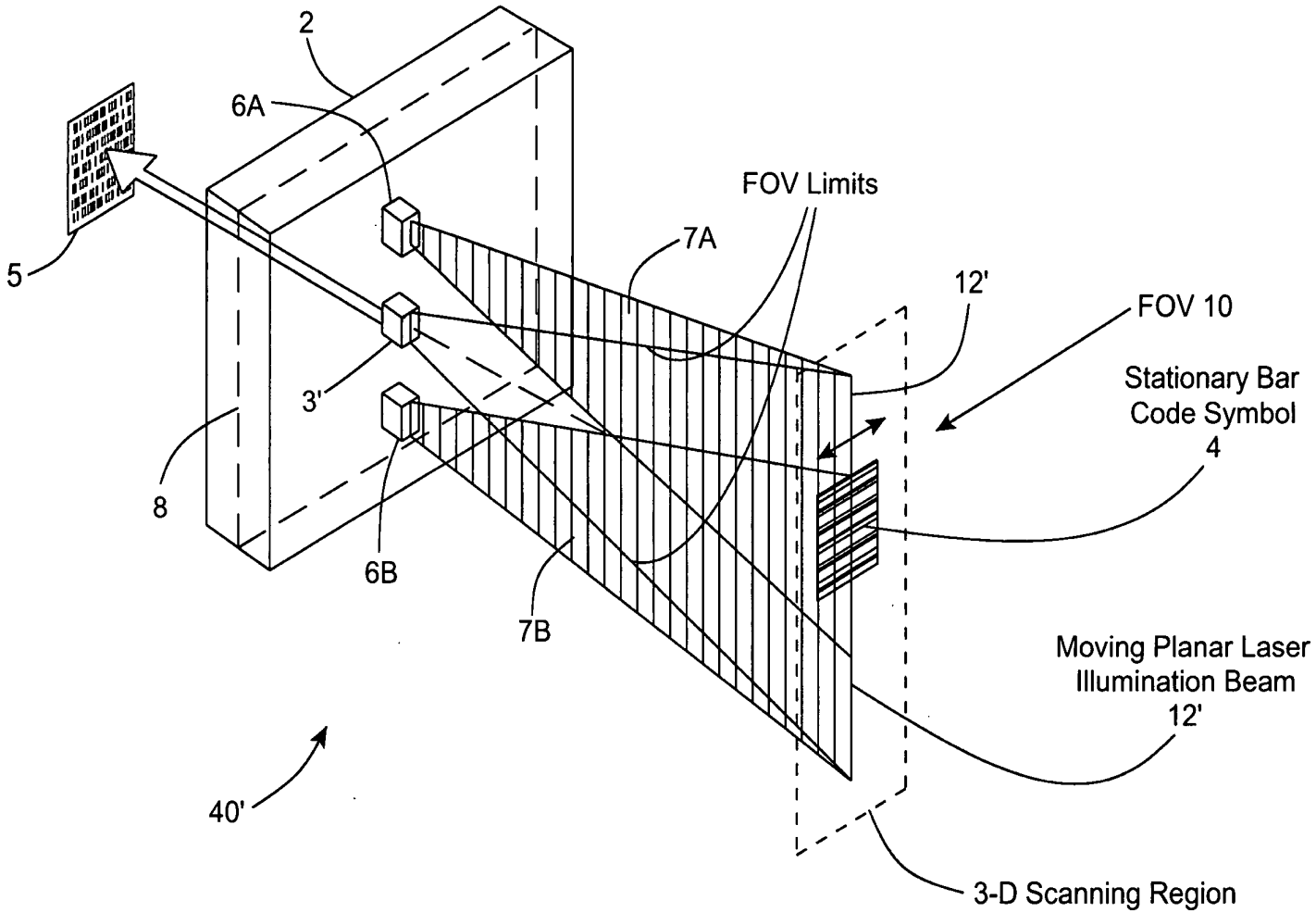

2
6A
FOV Limits
7A
12'
FOV 10
5
Stationary Bar
Code Symbol
4
3'
8
6B
7B
Moving Planar Laser
Illumination Beam
12'
40'
3-D Scanning Region

FIG. 2I1

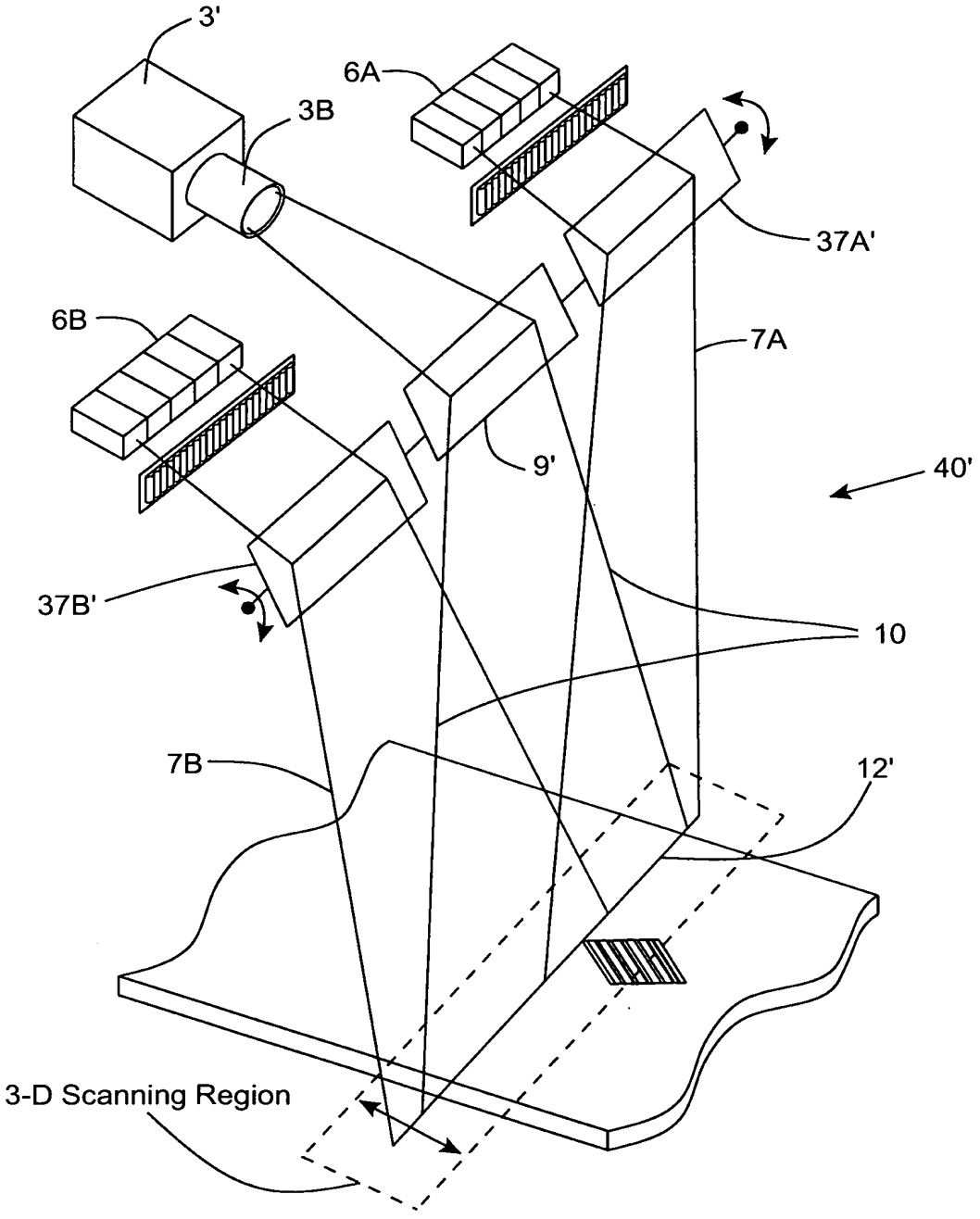


FIG. 2I2

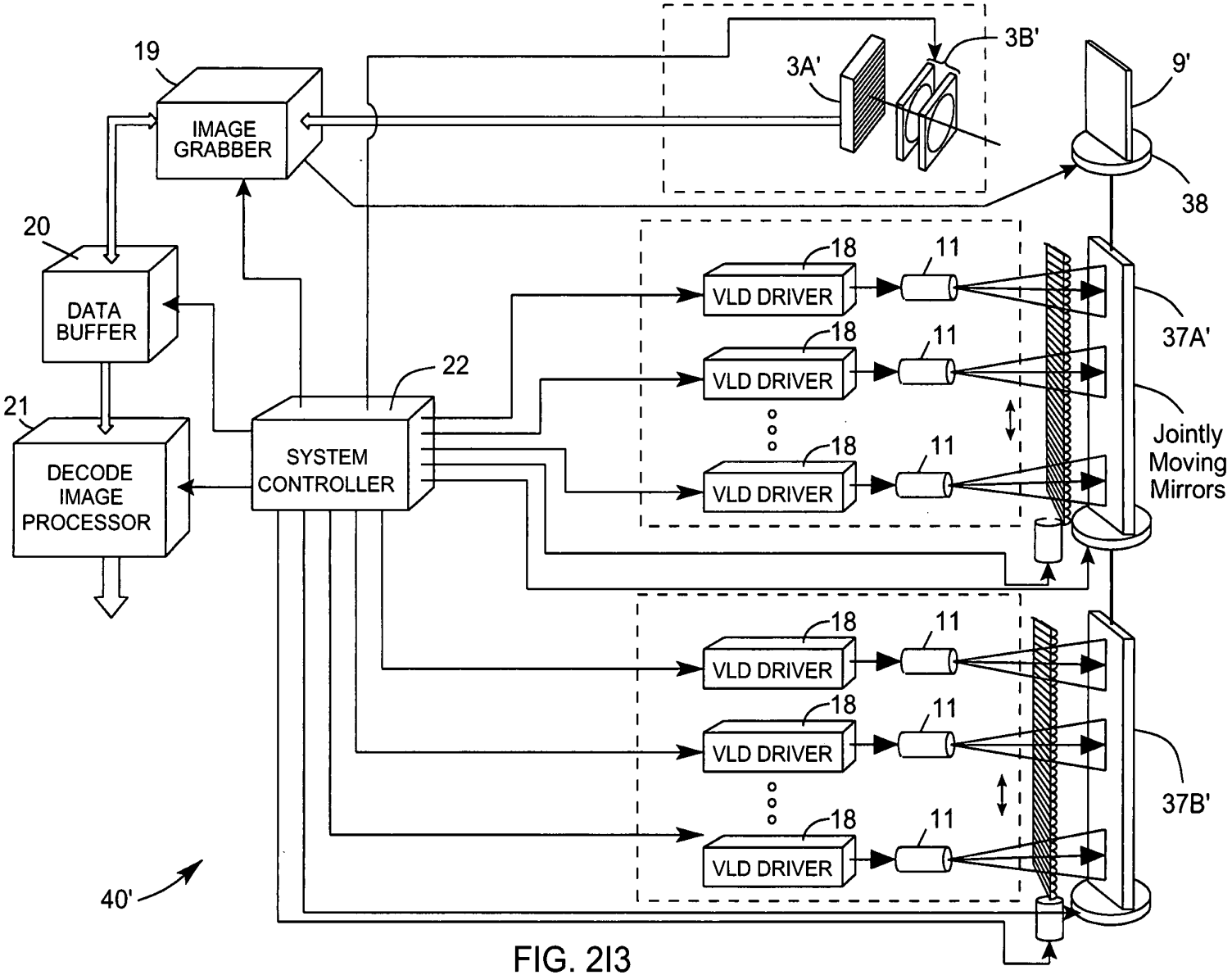

19
IMAGE GRABBER
3A'
3B'
9'
38
20
DATA BUFFER
21
DECODE IMAGE PROCESSOR
22
SYSTEM CONTROLLER
18
11
VLD DRIVER
37A'
Jointly Moving Mirrors
37B'
40'

FIG. 2I3

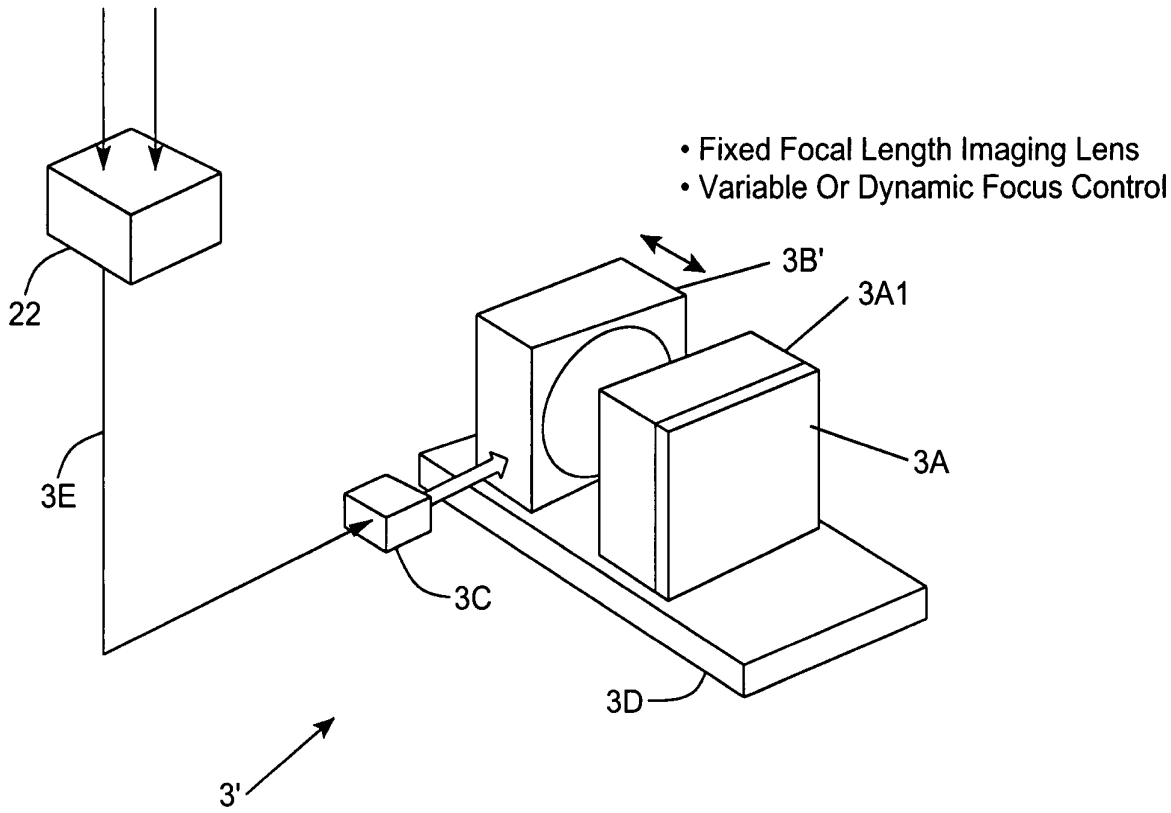

• Fixed Focal Length Imaging Lens
• Variable Or Dynamic Focus Control
22
3E
3B'
3A1
3A
3C
3D
3'

FIG. 2I4

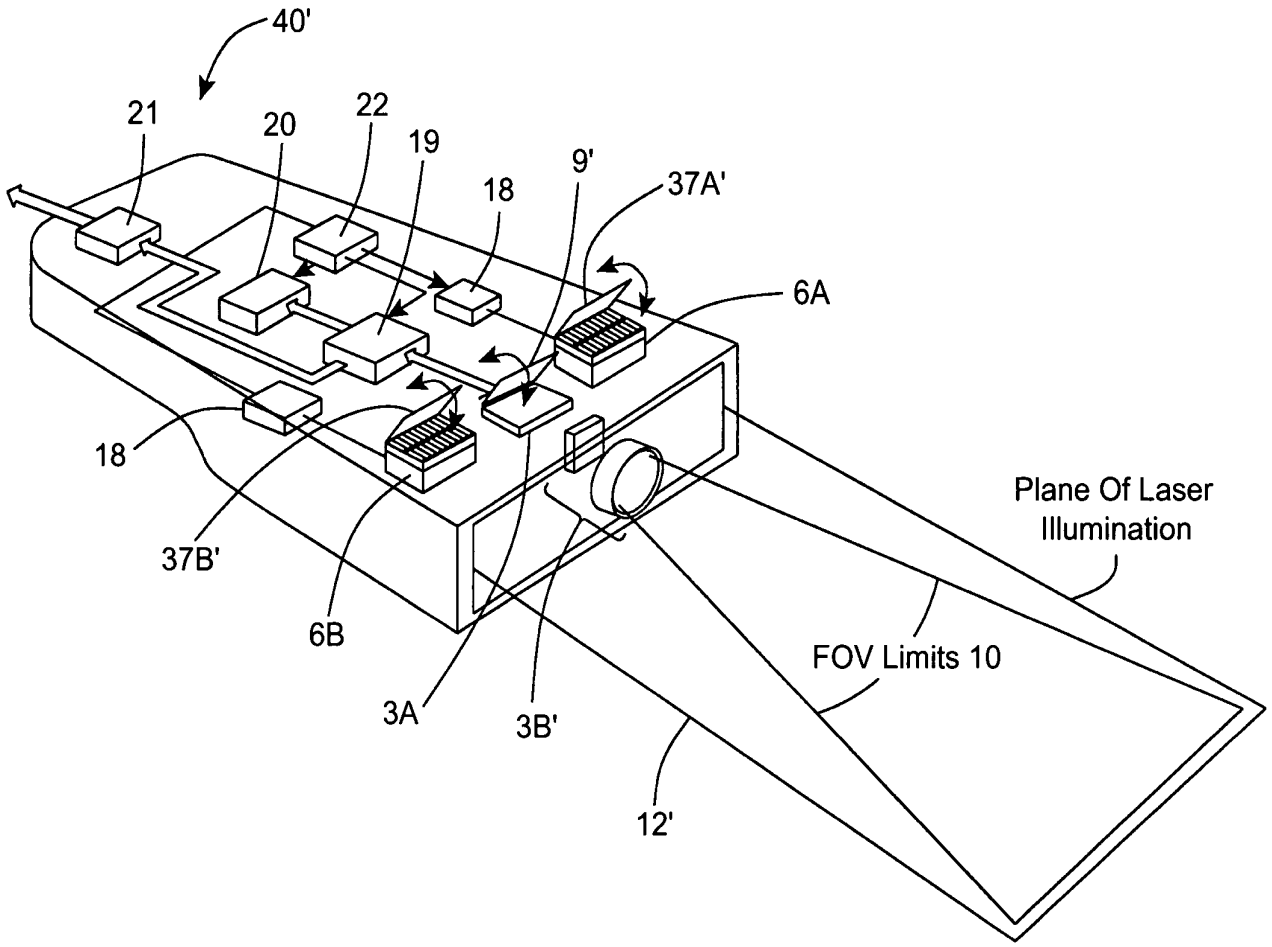

40'
21
20
22
19
18
9'
37A'
6A
18
37B'
6B
3A
3B'
12'
Plane Of Laser
Illumination
FOV Limits 10

FIG. 2I5

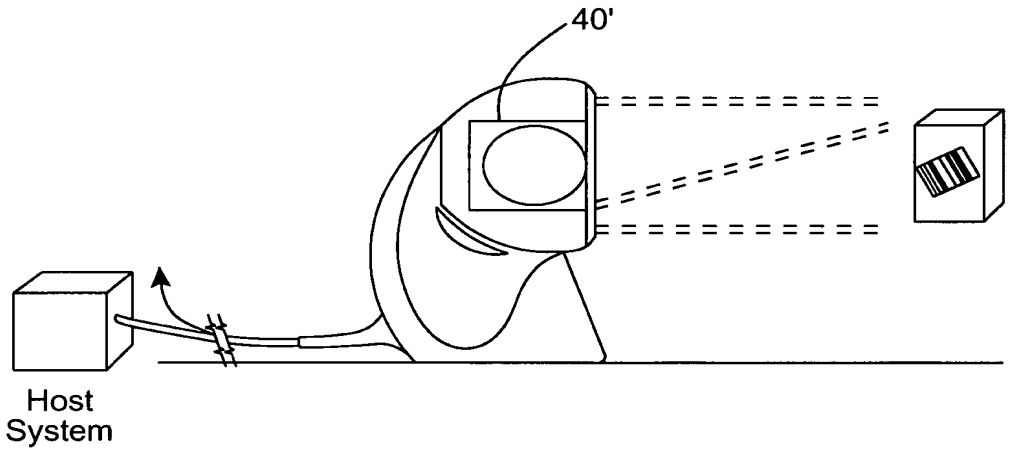


FIG. 2I6

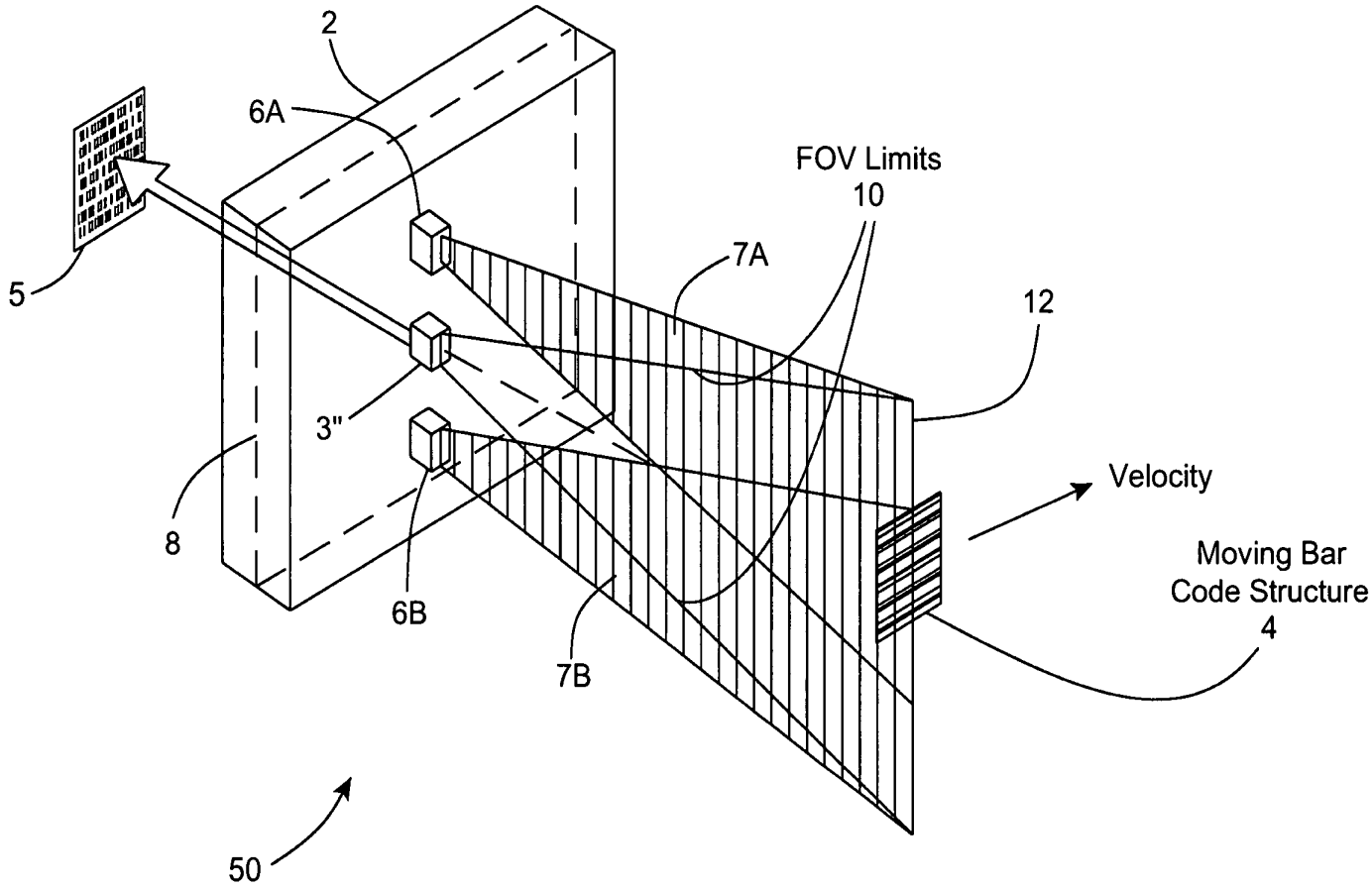

2
6A
FOV Limits
10
7A
12
5
3"
Velocity
8
Moving Bar
Code Structure
4
6B
7B
50

FIG. 3A

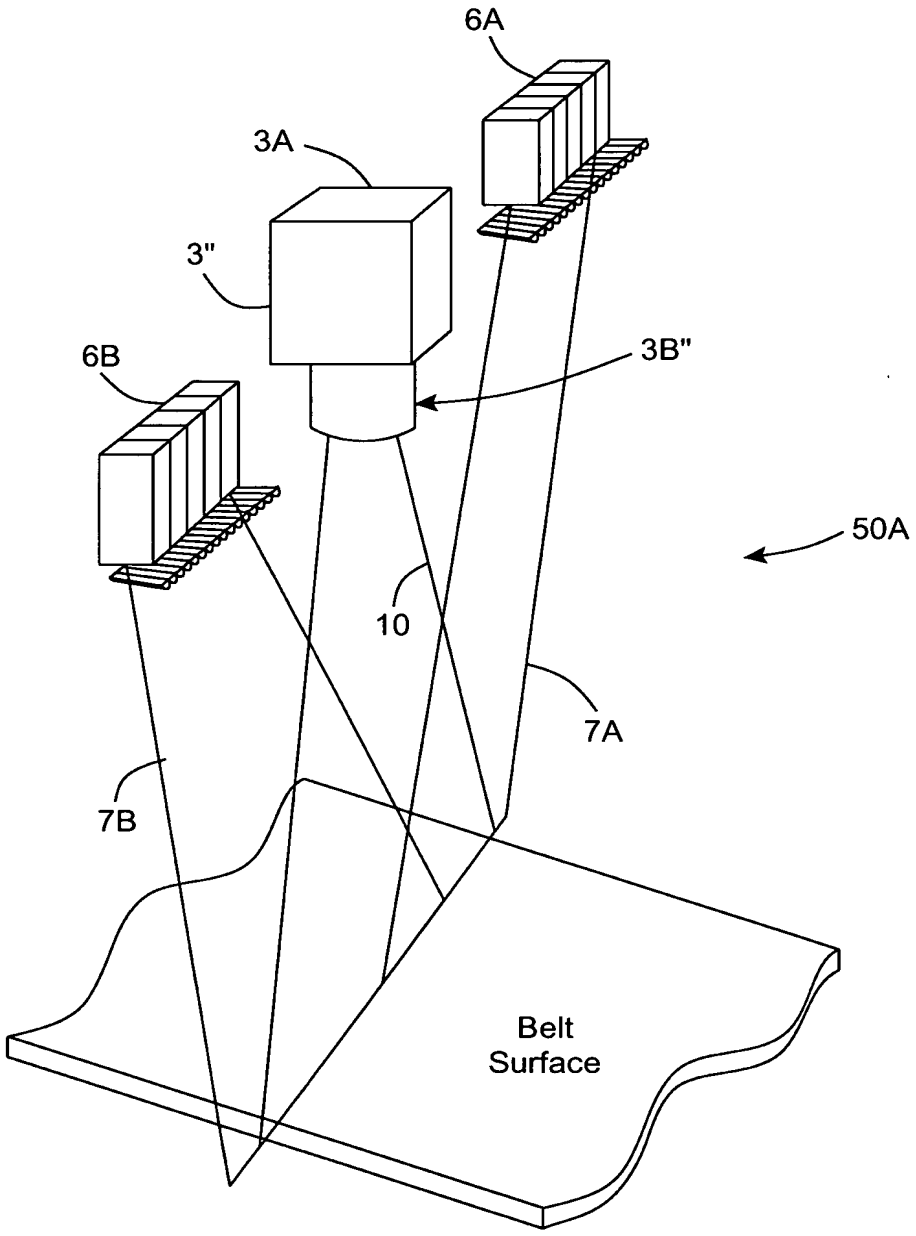


FIG. 3B1

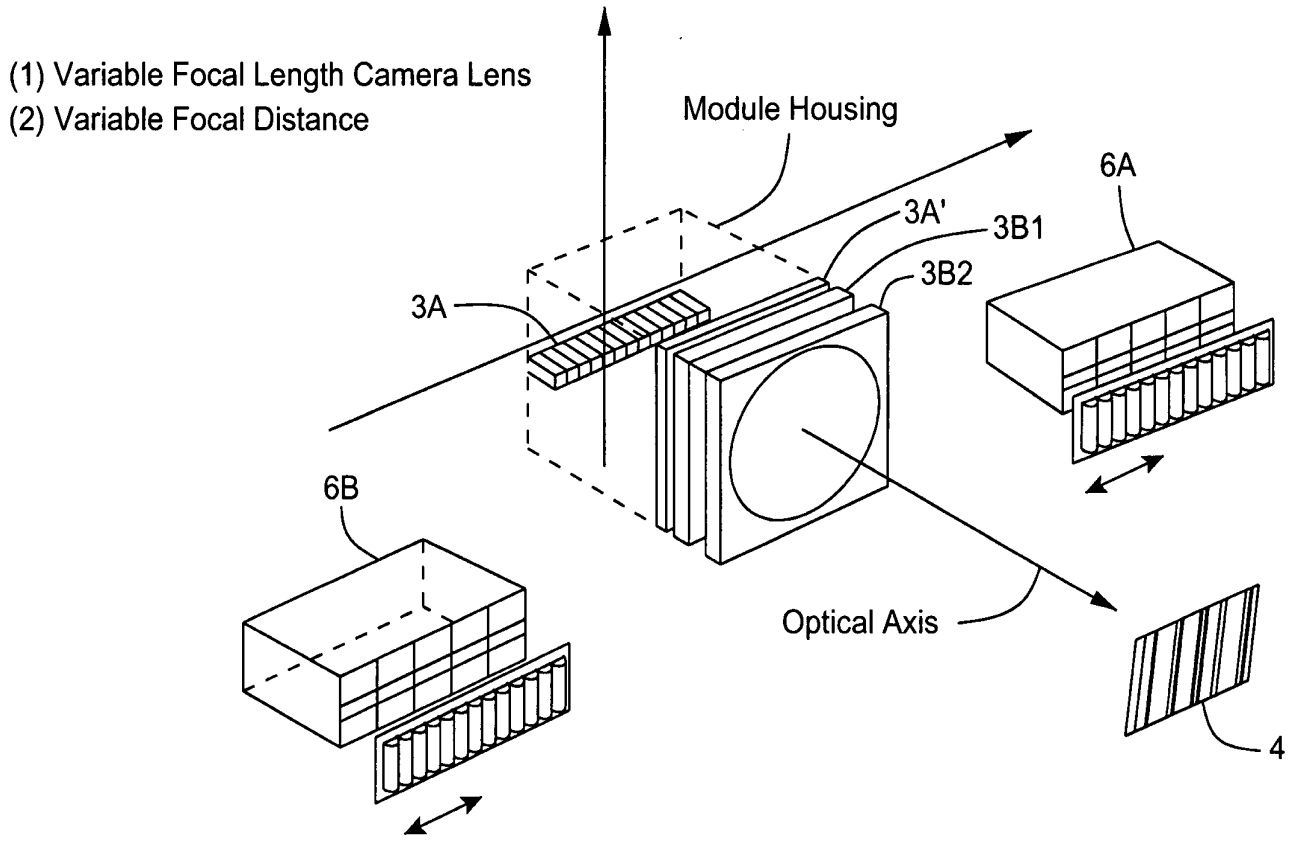

(1) Variable Focal Length Camera Lens
(2) Variable Focal Distance
Module Housing
6A
3A'
3B1
3B2
3A
6B
Optical Axis
4

FIG. 3B2

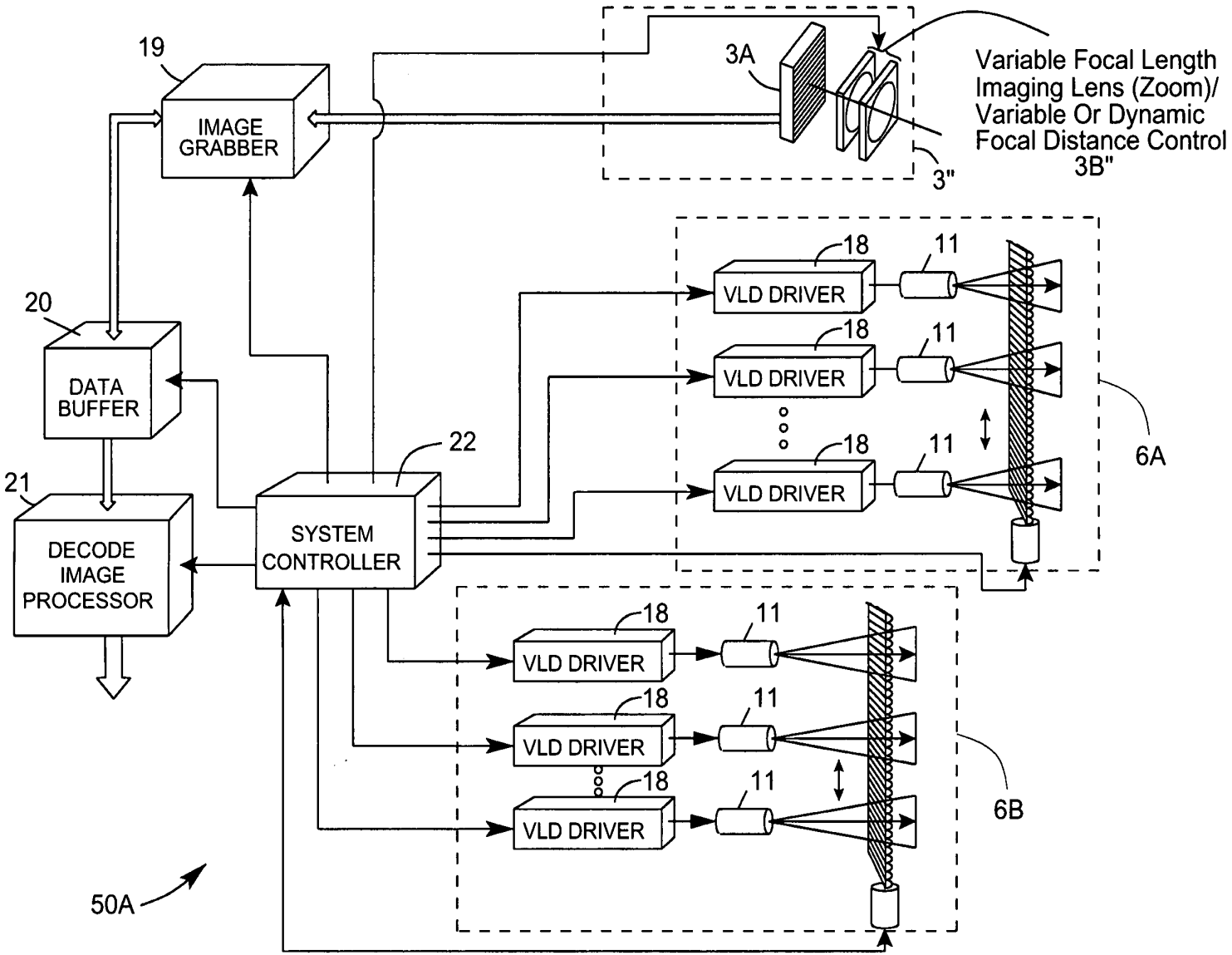
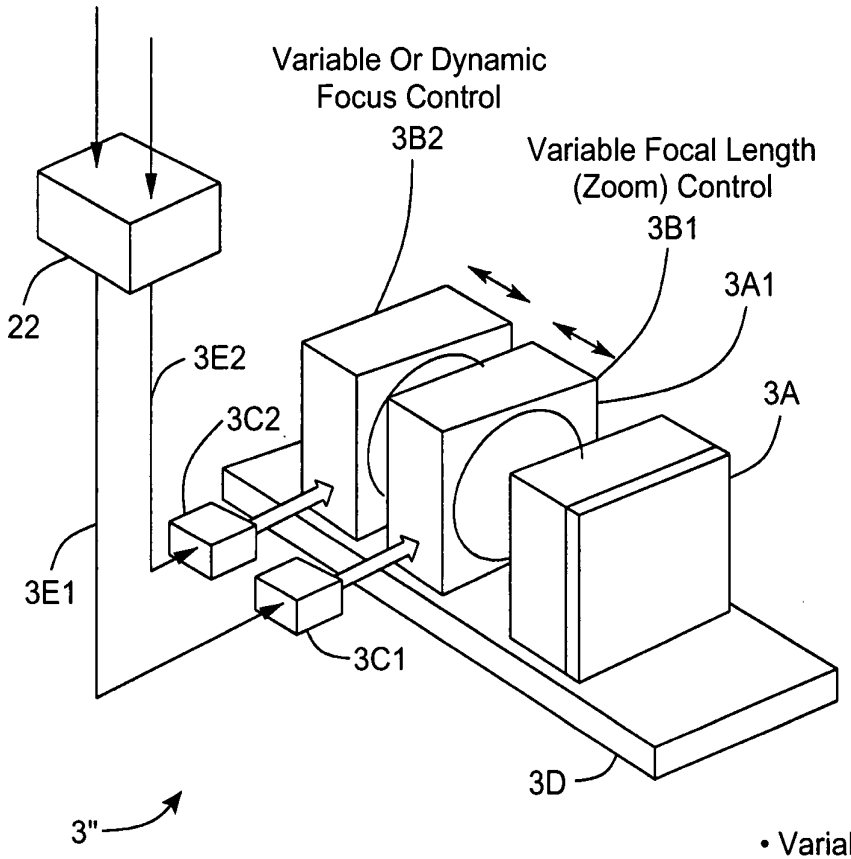

19
IMAGE GRABBER
3A
Variable Focal Length Imaging Lens (Zoom)/ Variable Or Dynamic Focal Distance Control 3B"
3"
20
DATA BUFFER
21
DECODE IMAGE PROCESSOR
22
SYSTEM CONTROLLER
18
11
VLD DRIVER
6A
6B
50A

FIG. 3C1



- Variable Focal Length Camera Lens
- Variable Focal Distance

FIG. 3C2

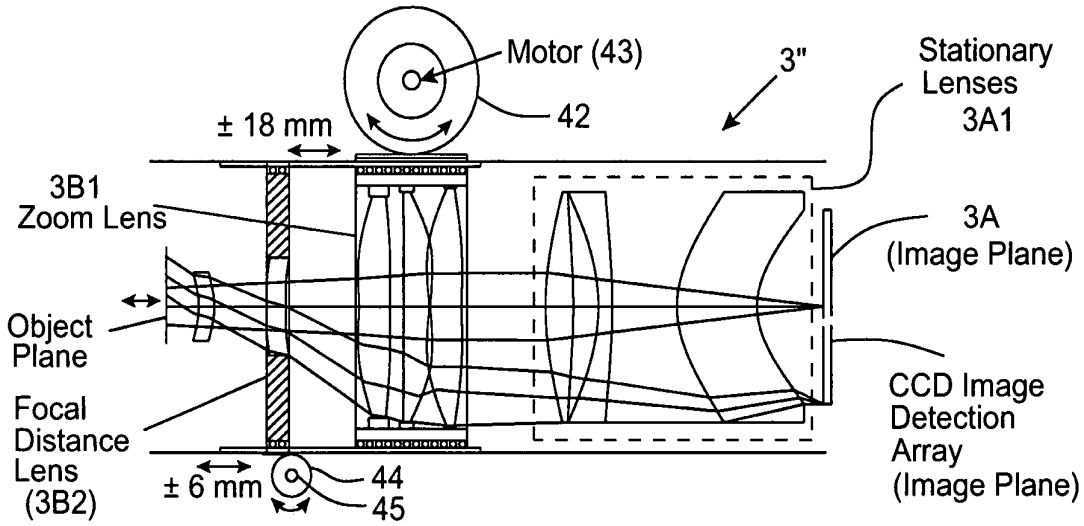

Motor (43)
42
3"
Stationary
Lenses
3A1
± 18 mm
3B1
Zoom Lens
3A
(Image Plane)
Object
Plane
Focal
Distance
Lens
(3B2)
± 6 mm
44
45
CCD Image
Detection
Array
(Image Plane)

FIG. 3D

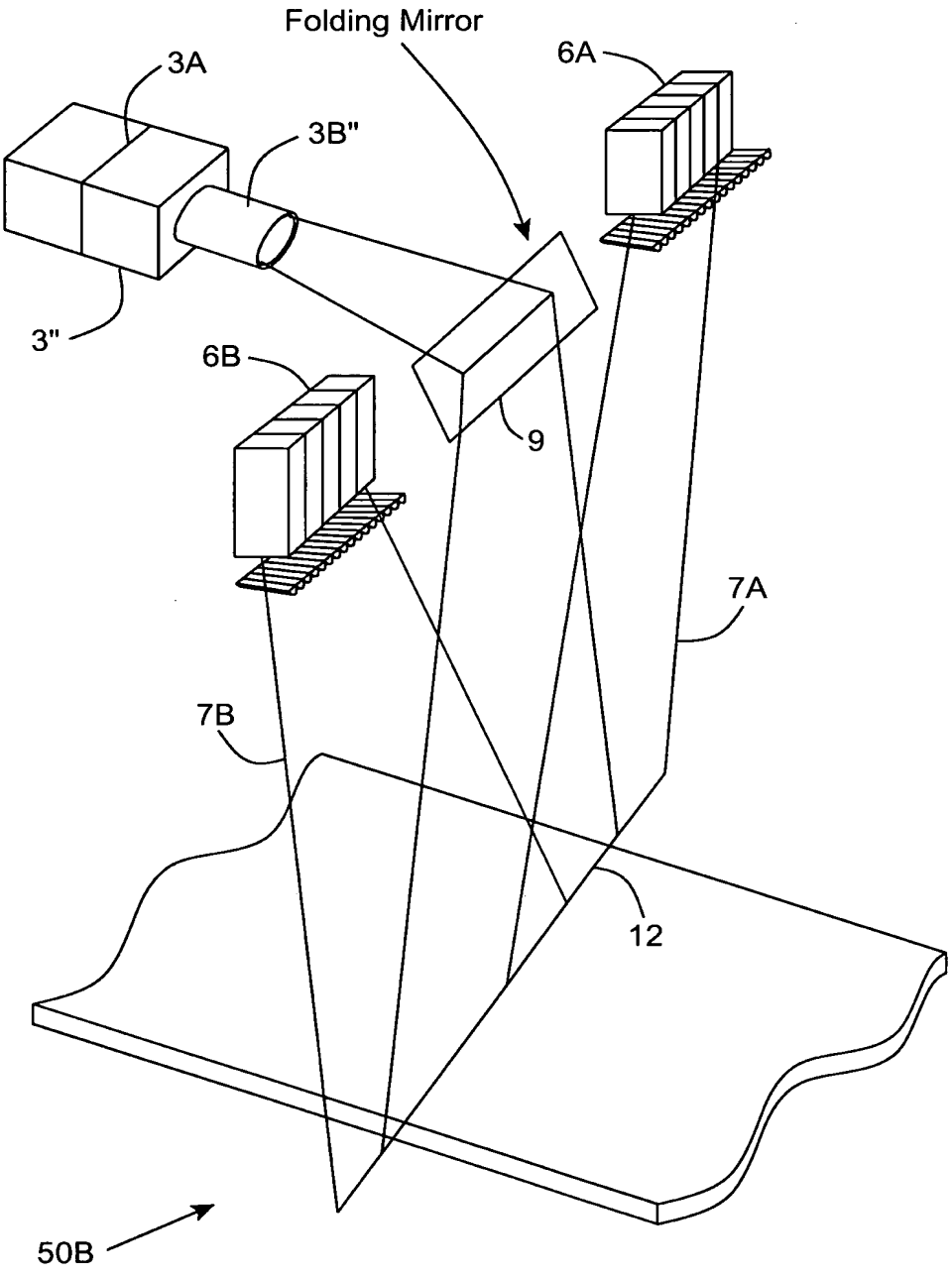


FIG. 3E1

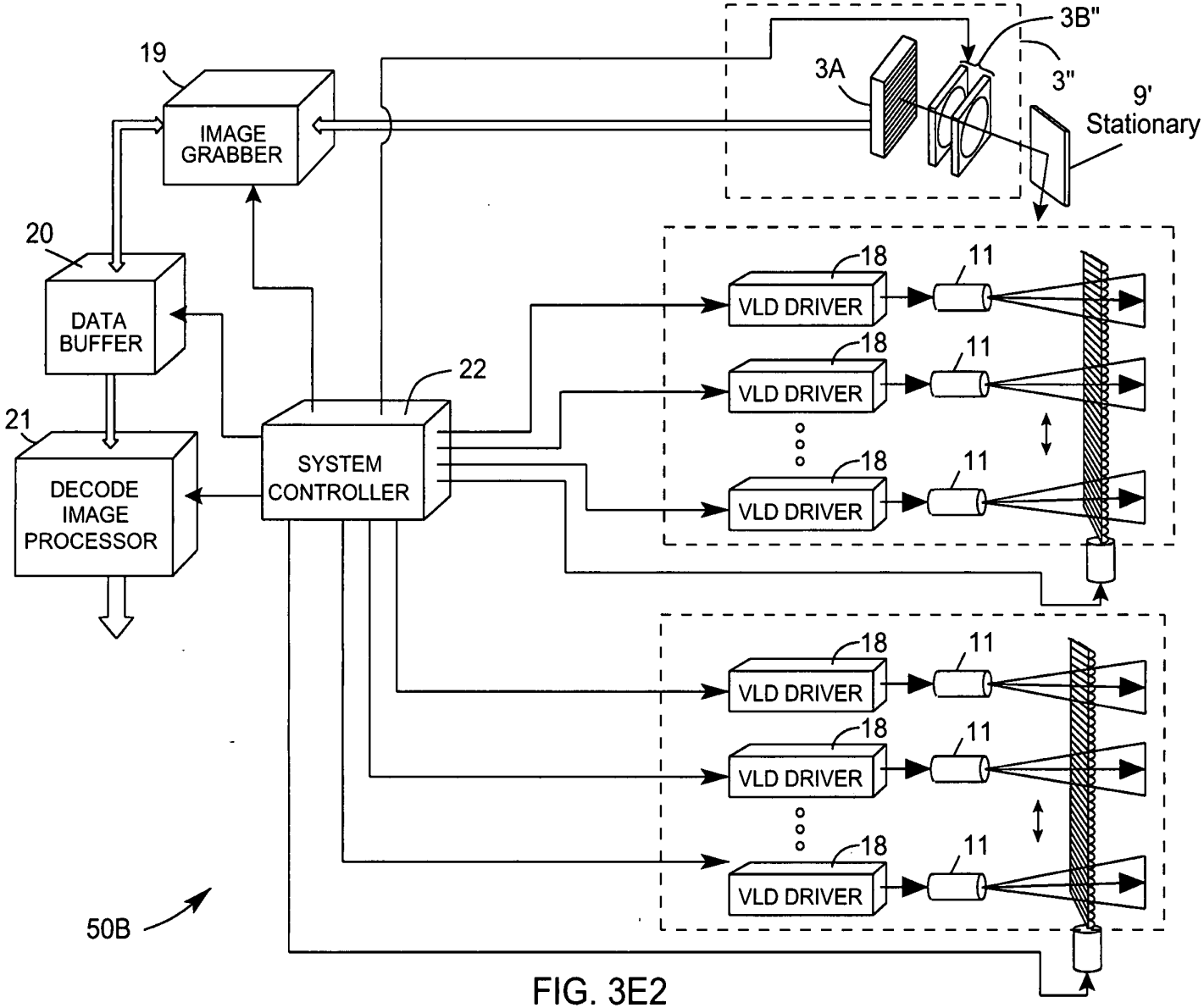

19
IMAGE GRABBER
3B"
3A
3"
9'
Stationary
20
DATA BUFFER
18
11
VLD DRIVER
22
21
SYSTEM CONTROLLER
DECODE IMAGE PROCESSOR
50B

FIG. 3E2

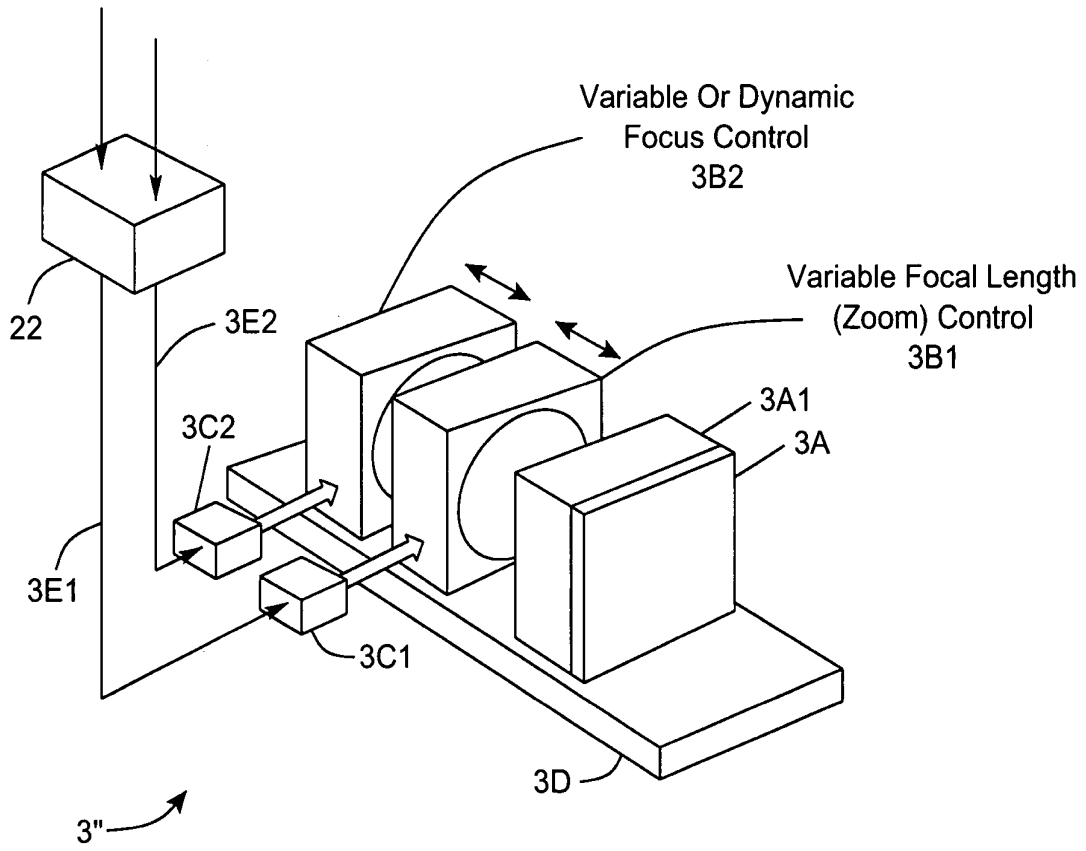

Variable Or Dynamic
Focus Control
3B2
Variable Focal Length
(Zoom) Control
3B1
22
3E2
3C2
3A1
3A
3E1
3C1
3D
3"

FIG. 3E3

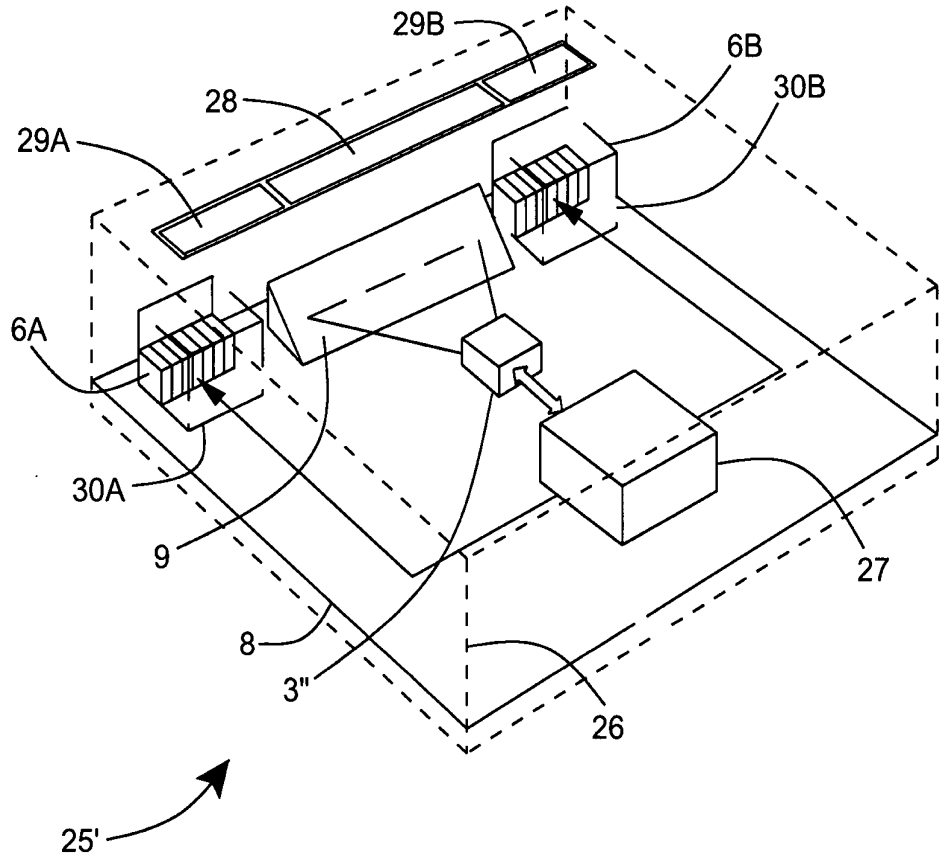


FIG. 3E4

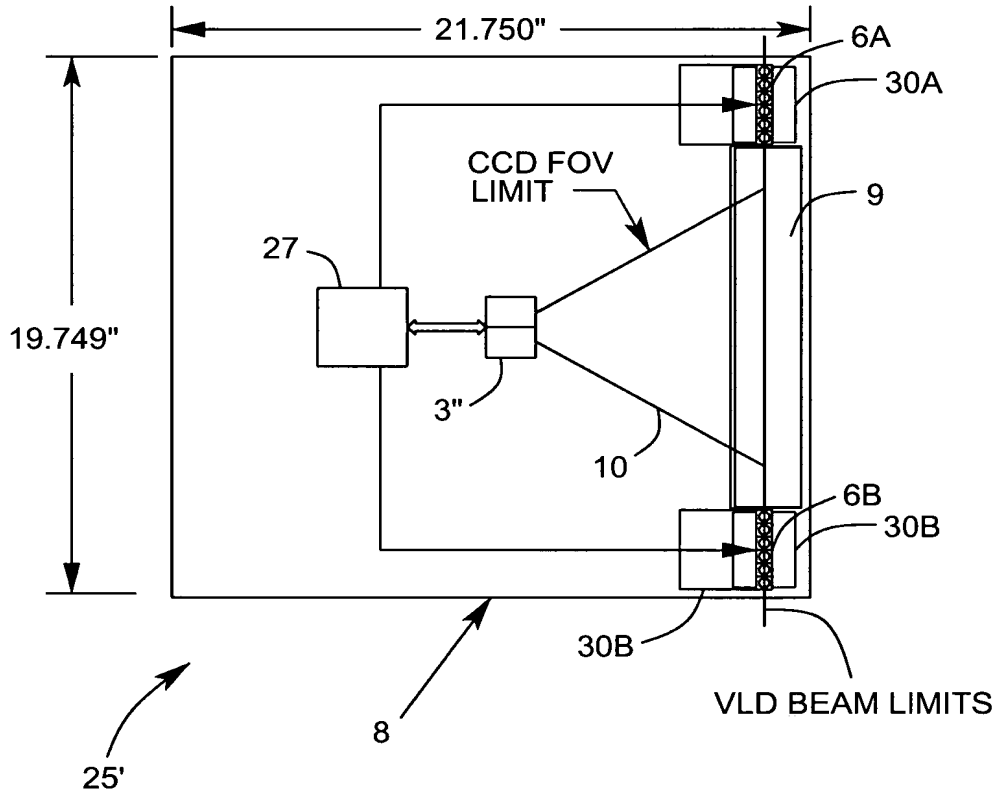

21.750"
6A
30A
CCD FOV
LIMIT
9
27
19.749"
3"
10
6B
30B
30B
VLD BEAM LIMITS
8
25'

FIG. 3E5

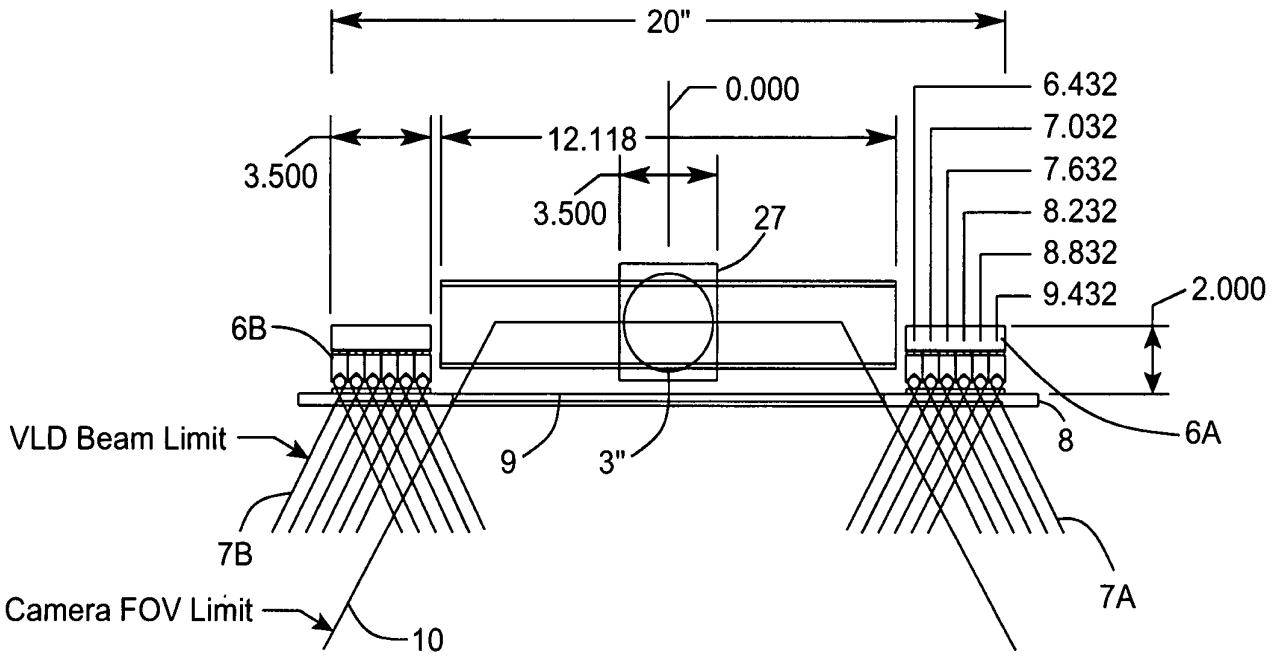

20"
0.000
6.432
7.032
7.632
8.232
8.832
9.432
12.118
3.500
3.500
27
2.000
6B
VLD Beam Limit
9
3"
8
6A
7B
7A
Camera FOV Limit
10

FIG. 3E6

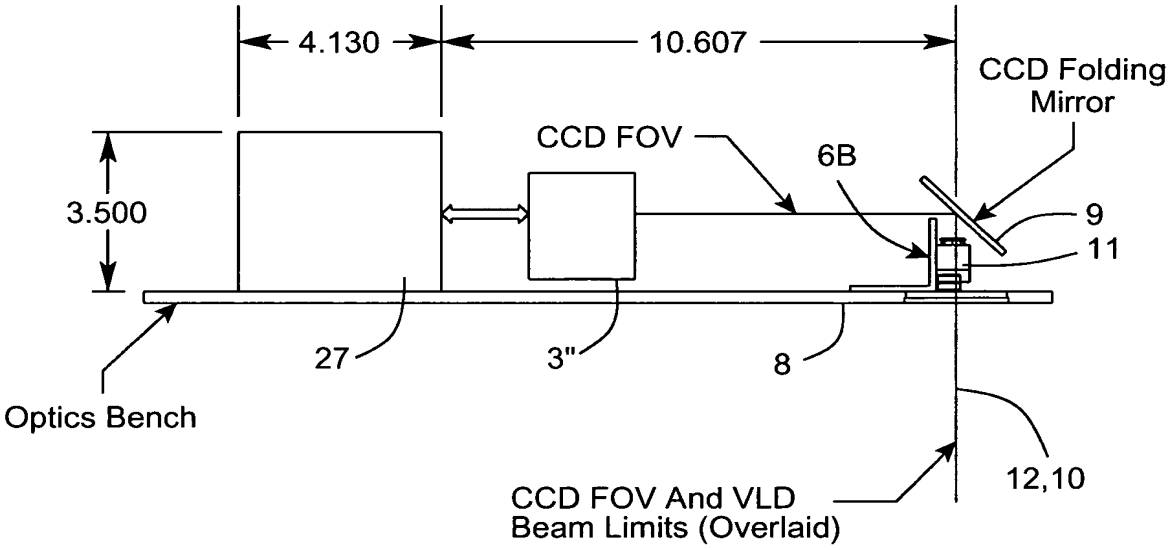

4.130
10.607
CCD Folding Mirror
CCD FOV
6B
3.500
9
11
27
3"
8
Optics Bench
12,10
CCD FOV And VLD Beam Limits (Overlaid)

FIG. 3E7

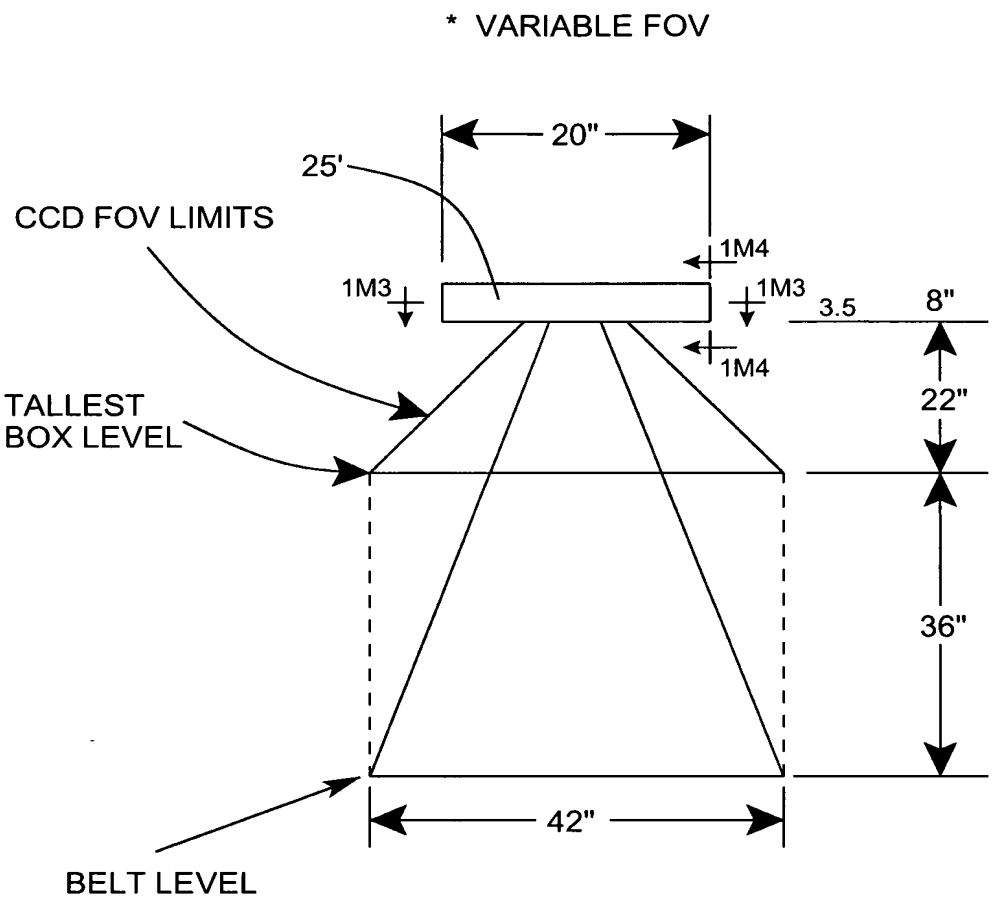

* VARIABLE FOV
20"
25'
CCD FOV LIMITS
1M4
1M3
1M3
3.5
8"
1M4
22"
TALLEST
BOX LEVEL
36"
42"
BELT LEVEL

FIG. 3E8

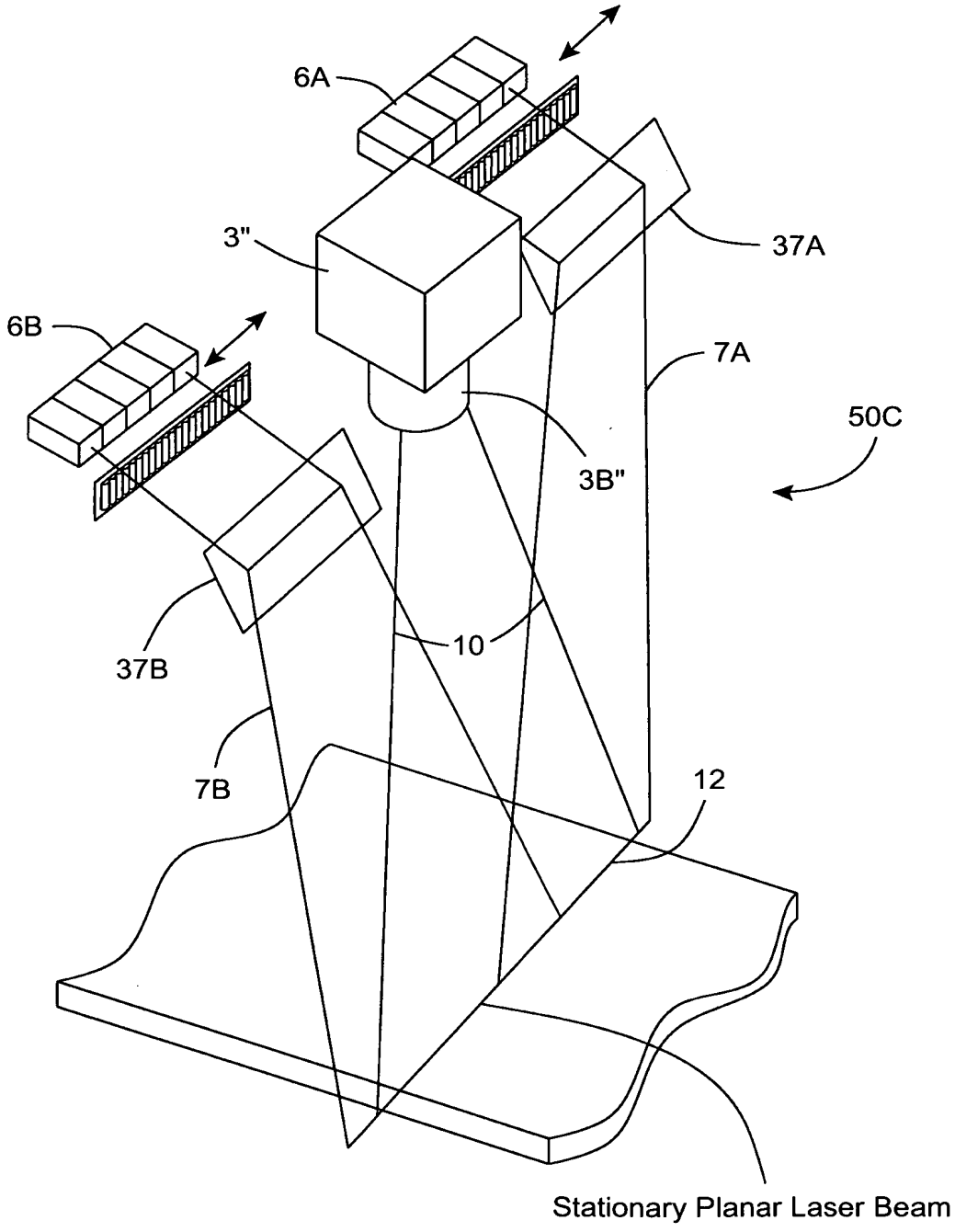


FIG. 3F1

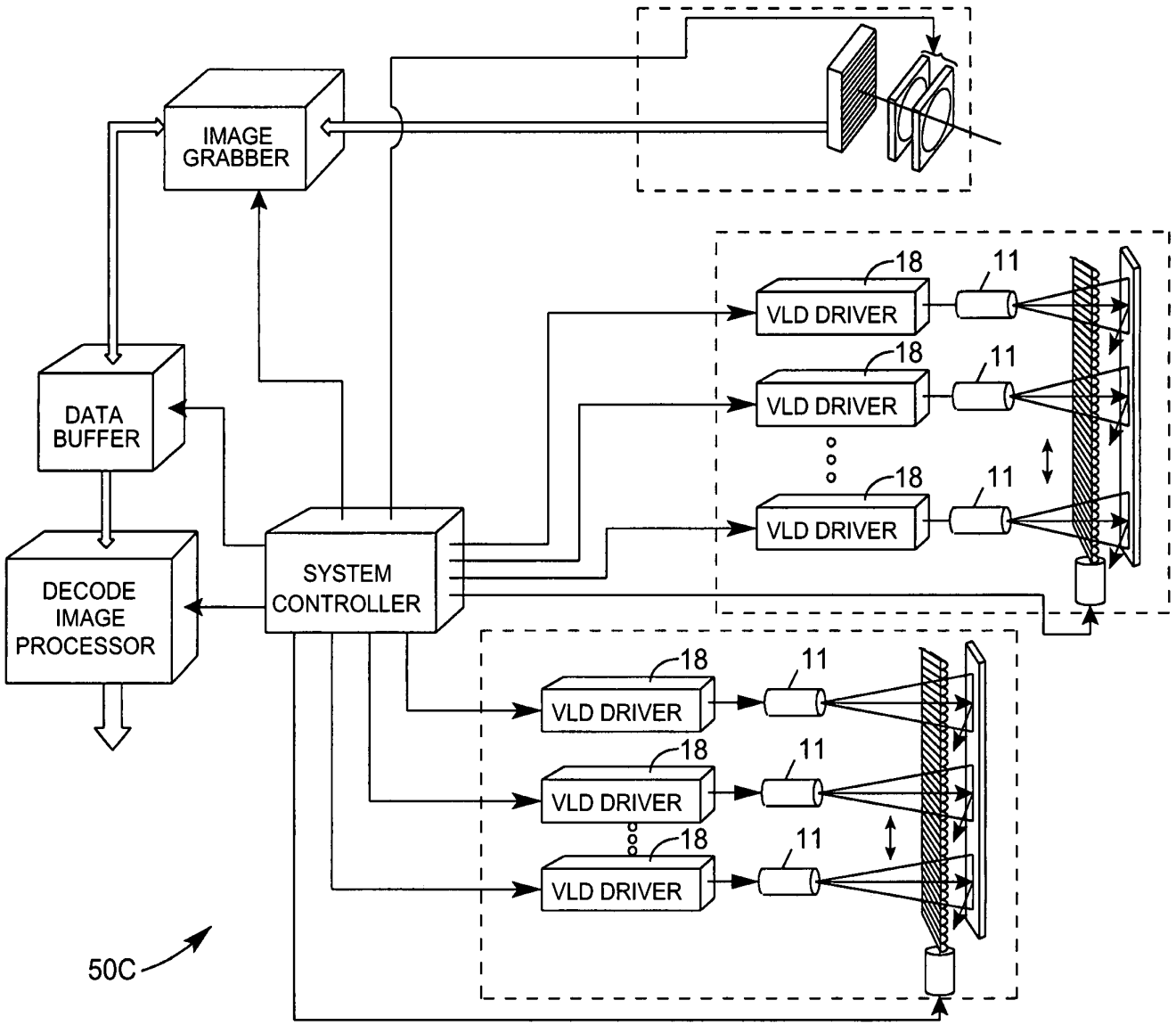


IMAGE GRABBER
DATA BUFFER
DECODE IMAGE PROCESSOR
SYSTEM CONTROLLER
VLD DRIVER
18
11
50C

FIG. 3F2

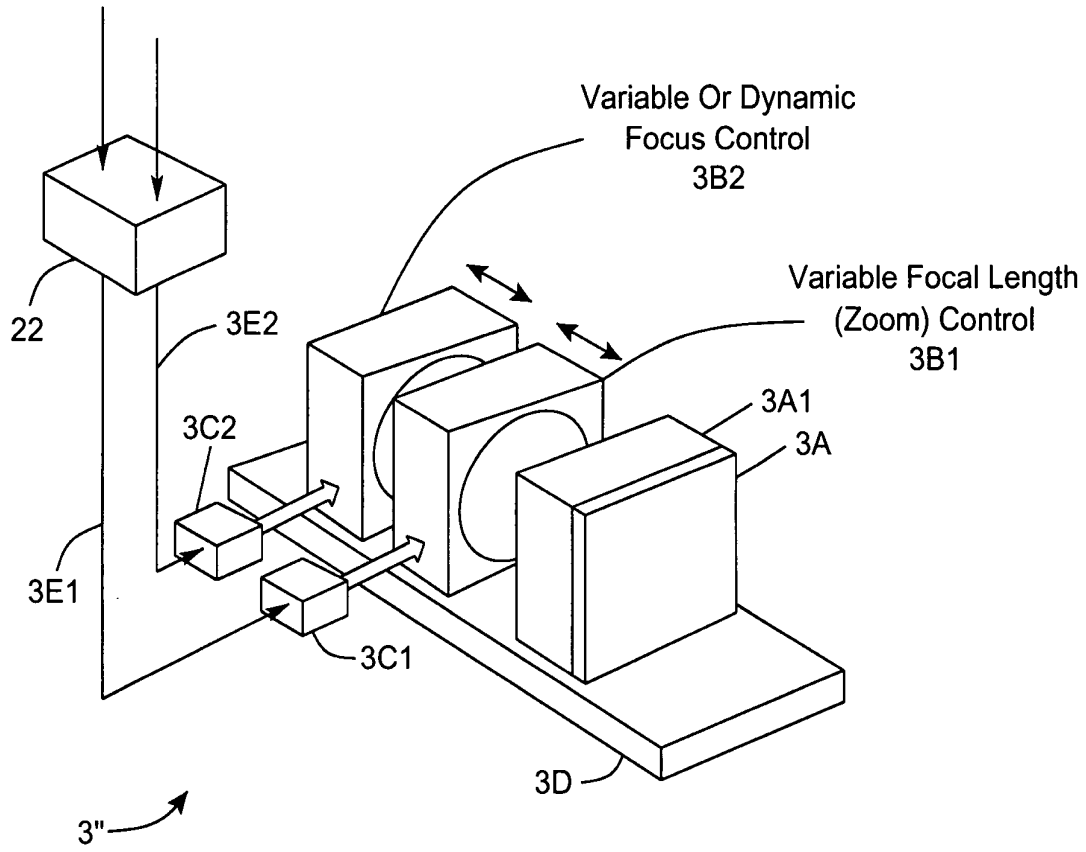

Variable Or Dynamic
Focus Control
3B2
Variable Focal Length
(Zoom) Control
3B1
22
3E2
3C2
3A1
3A
3E1
3C1
3D
3"

FIG. 3F3

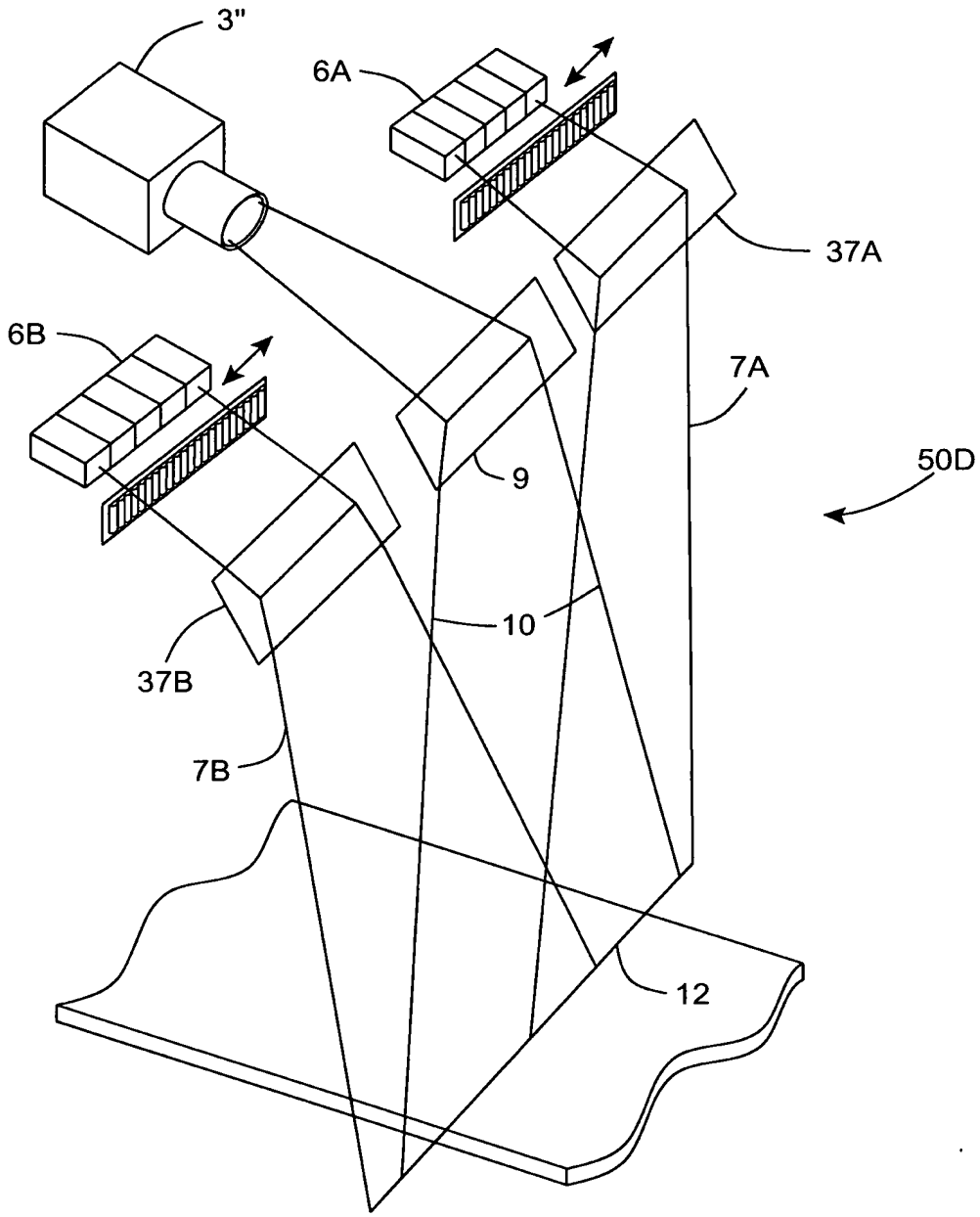


FIG. 3G1

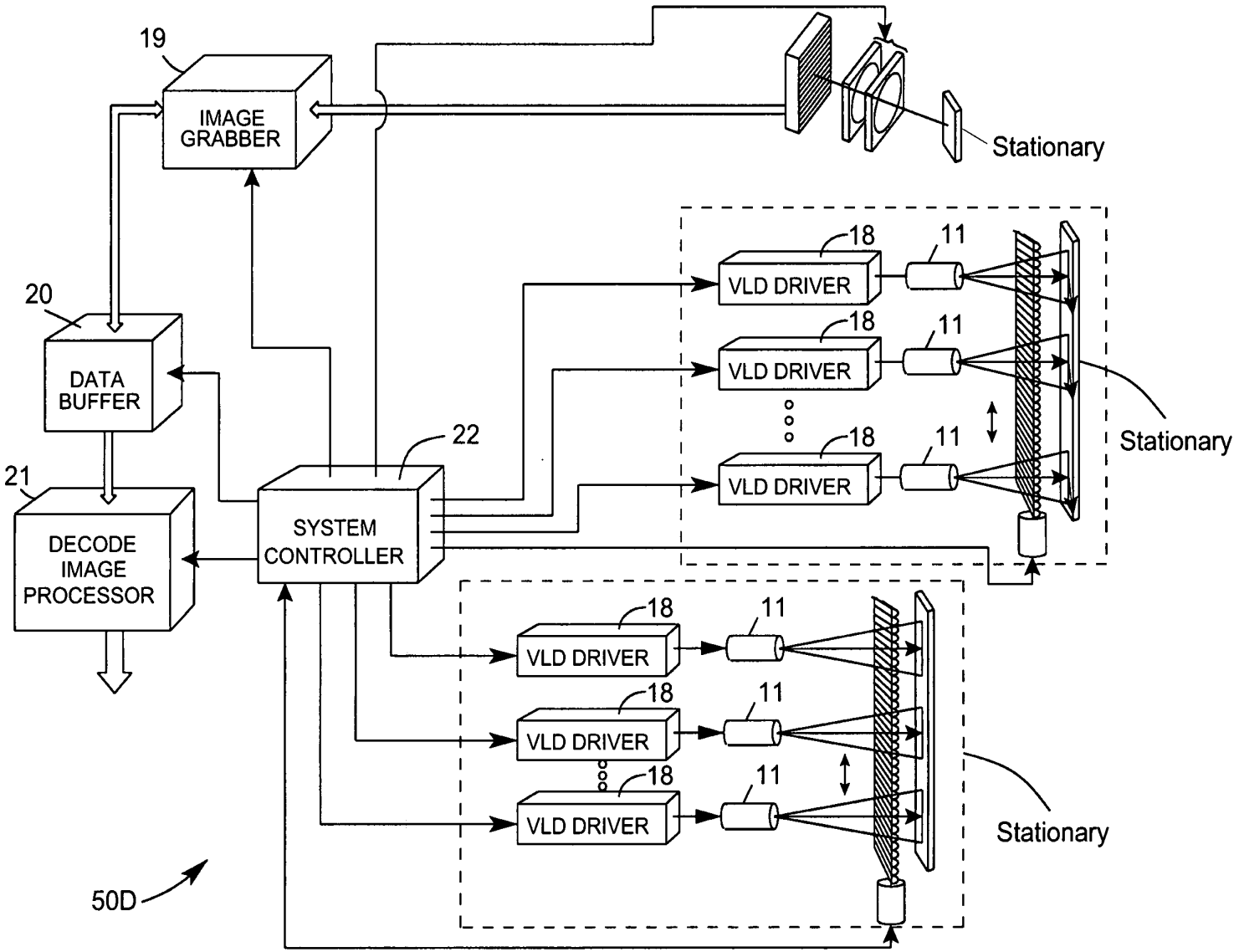

19
IMAGE GRABBER
Stationary
20
DATA BUFFER
21
DECODE IMAGE PROCESSOR
22
SYSTEM CONTROLLER
18
11
VLD DRIVER
VLD DRIVER
VLD DRIVER
Stationary
VLD DRIVER
VLD DRIVER
VLD DRIVER
Stationary
50D

FIG. 3G2

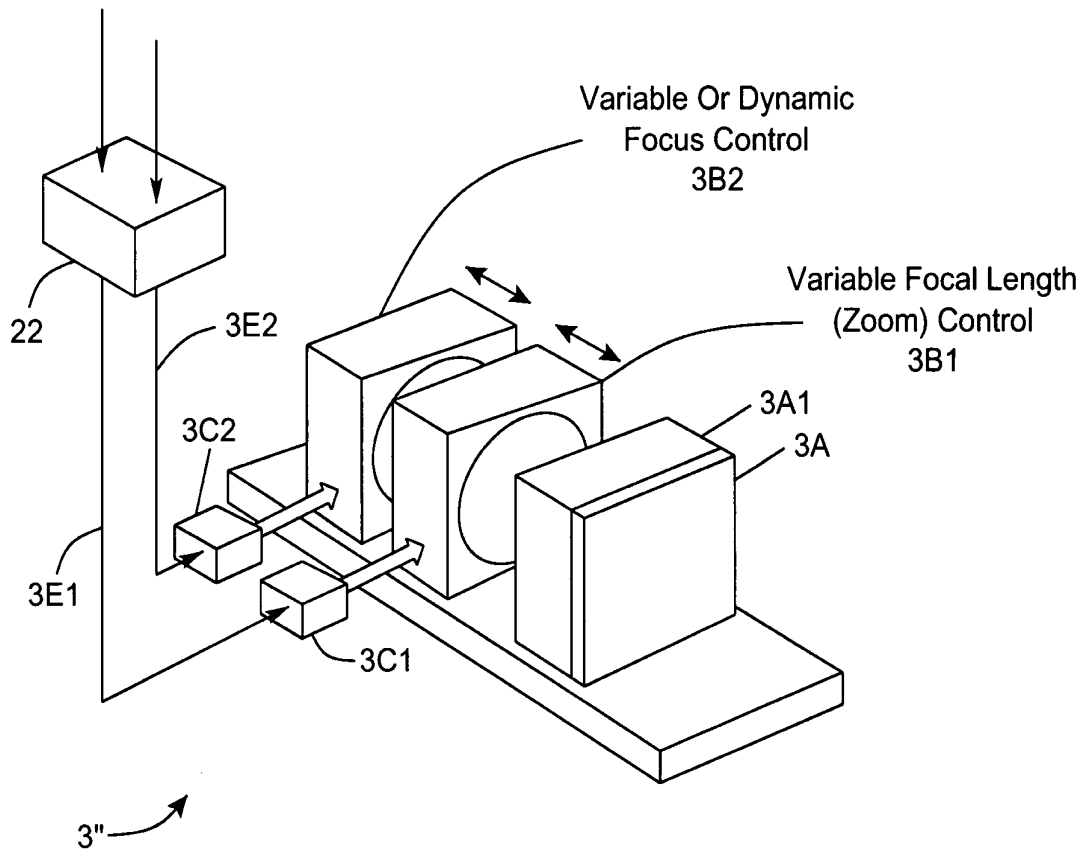

Variable Or Dynamic
Focus Control
3B2
Variable Focal Length
(Zoom) Control
3B1
22
3E2
3C2
3A1
3A
3E1
3C1
3"

FIG. 3G3

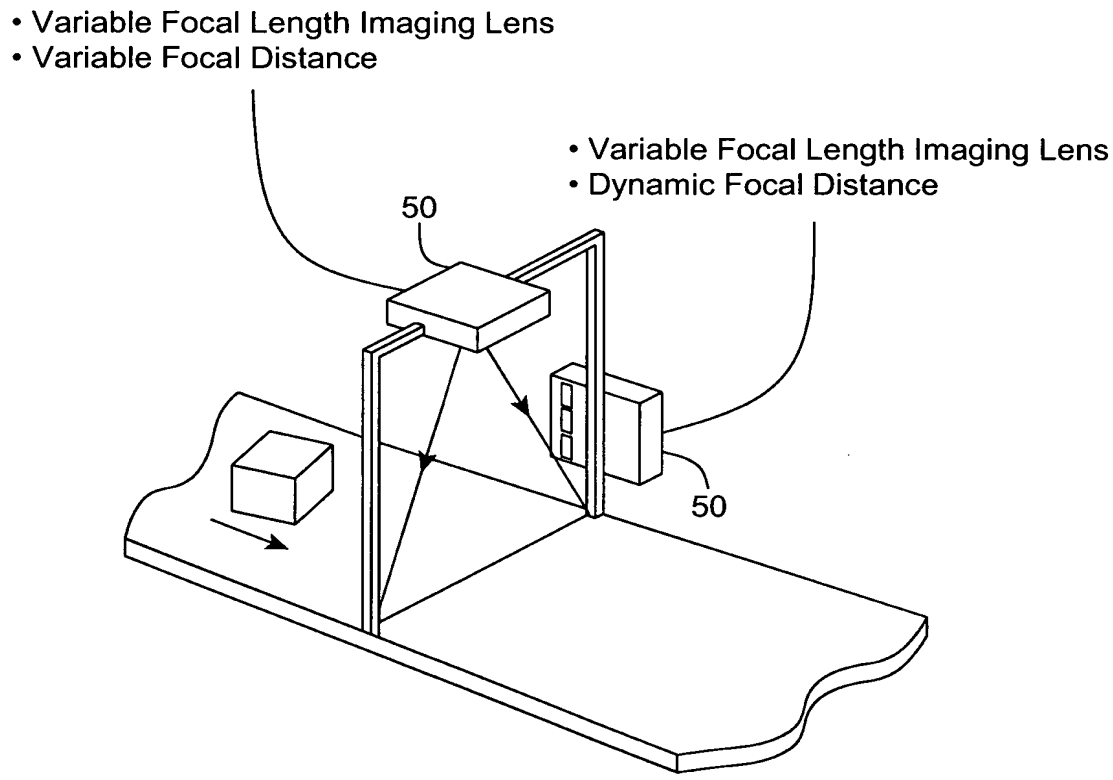

• Variable Focal Length Imaging Lens
• Variable Focal Distance
• Variable Focal Length Imaging Lens
• Dynamic Focal Distance
50
50

FIG. 3H

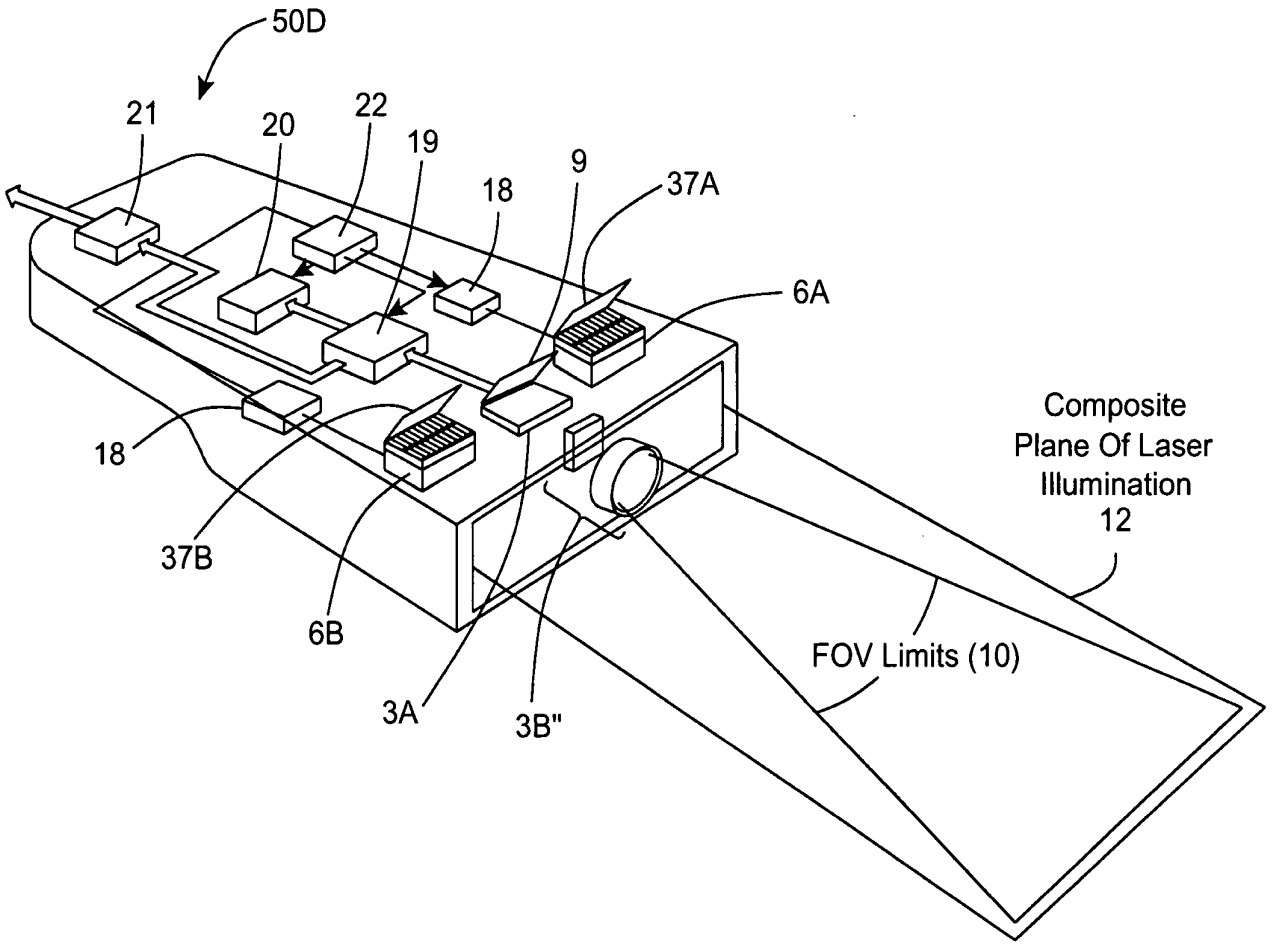

50D
21
20
22
19
18
9
37A
6A
18
37B
6B
3A
3B"
Composite
Plane Of Laser
Illumination
12
FOV Limits (10)

FIG. 3I

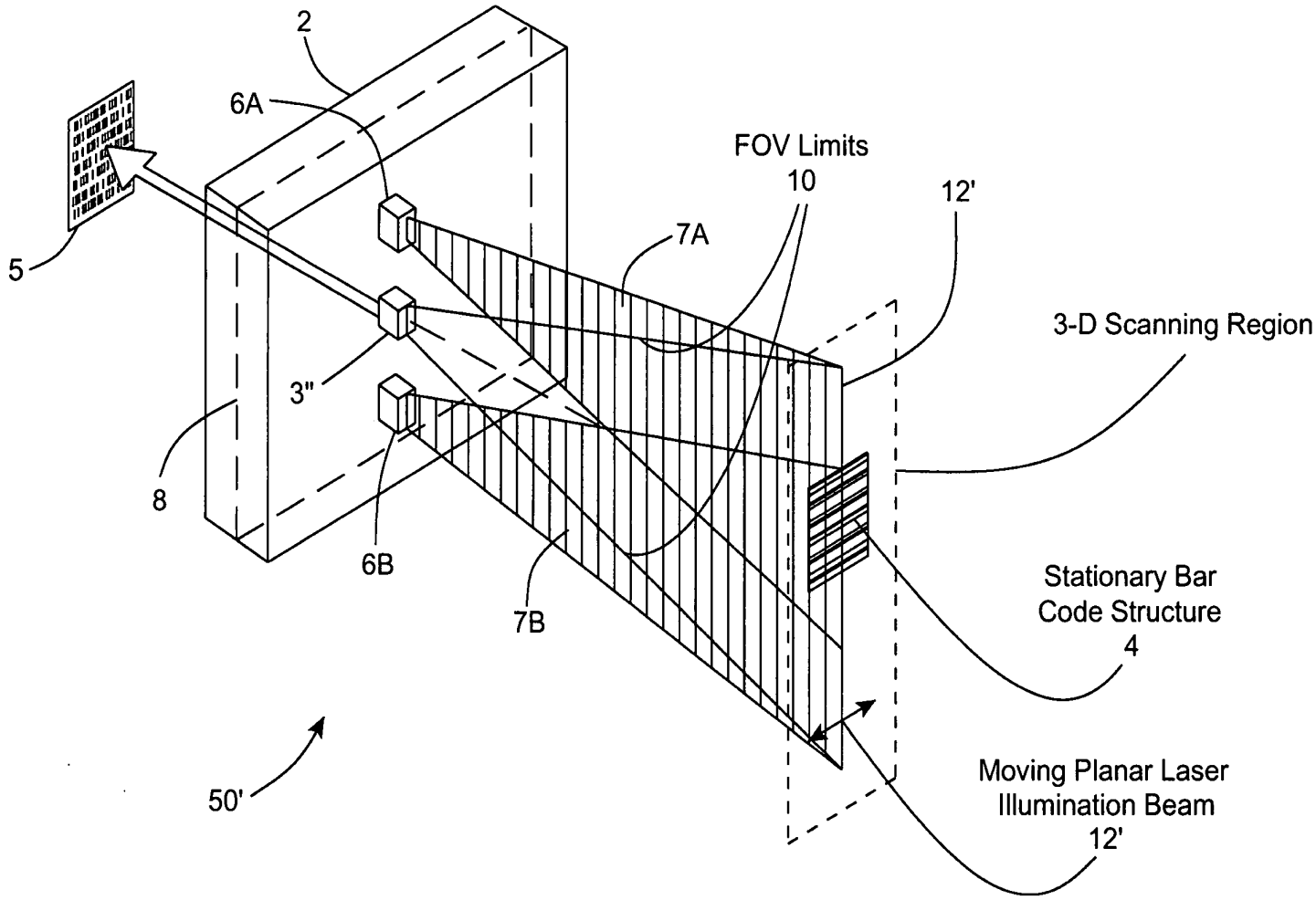

2
6A
FOV Limits
10
12'
7A
5
3-D Scanning Region
3"
8
6B
7B
Stationary Bar
Code Structure
4
50'
Moving Planar Laser
Illumination Beam
12'

FIG. 3J1

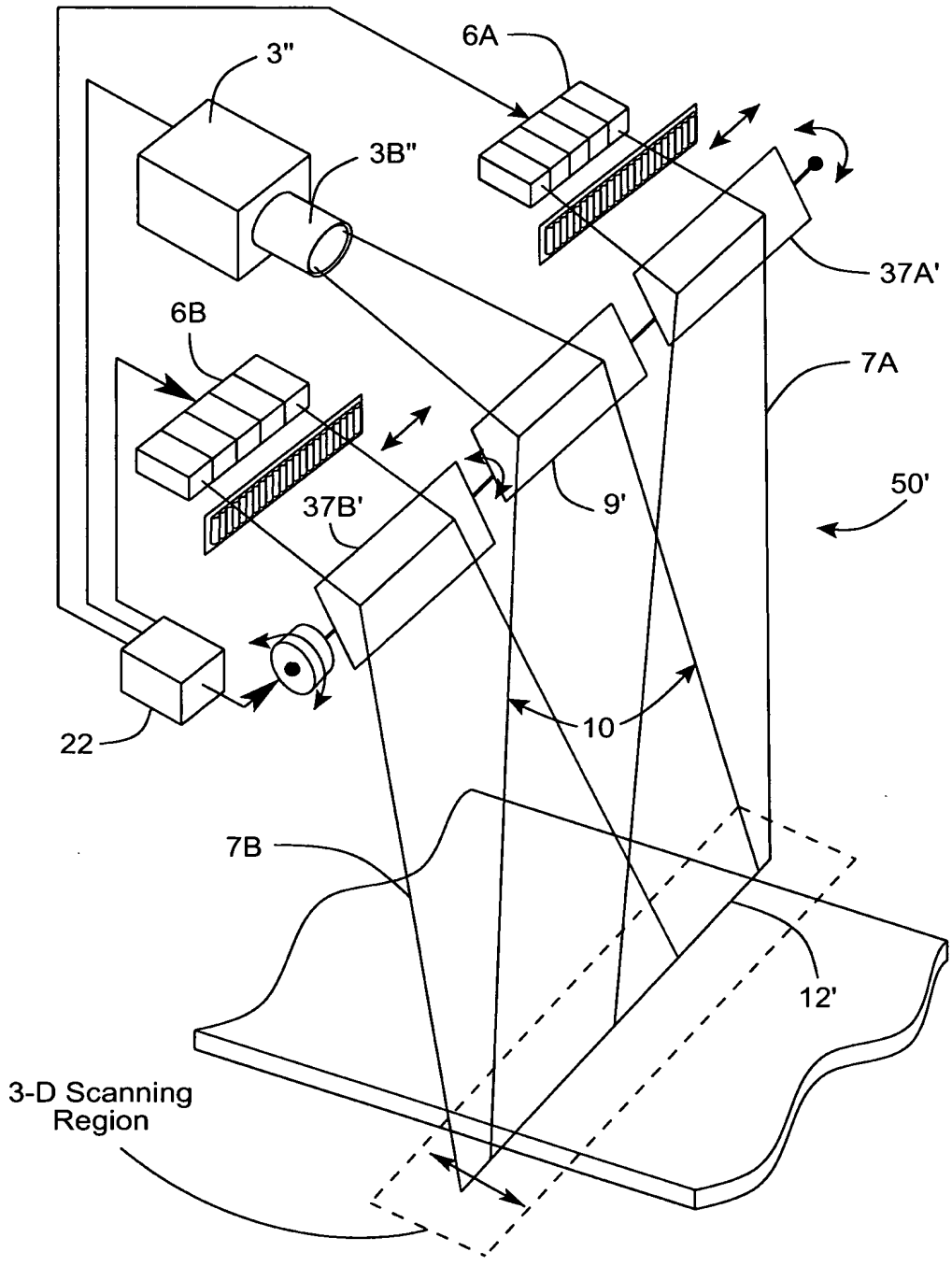


FIG. 3J2

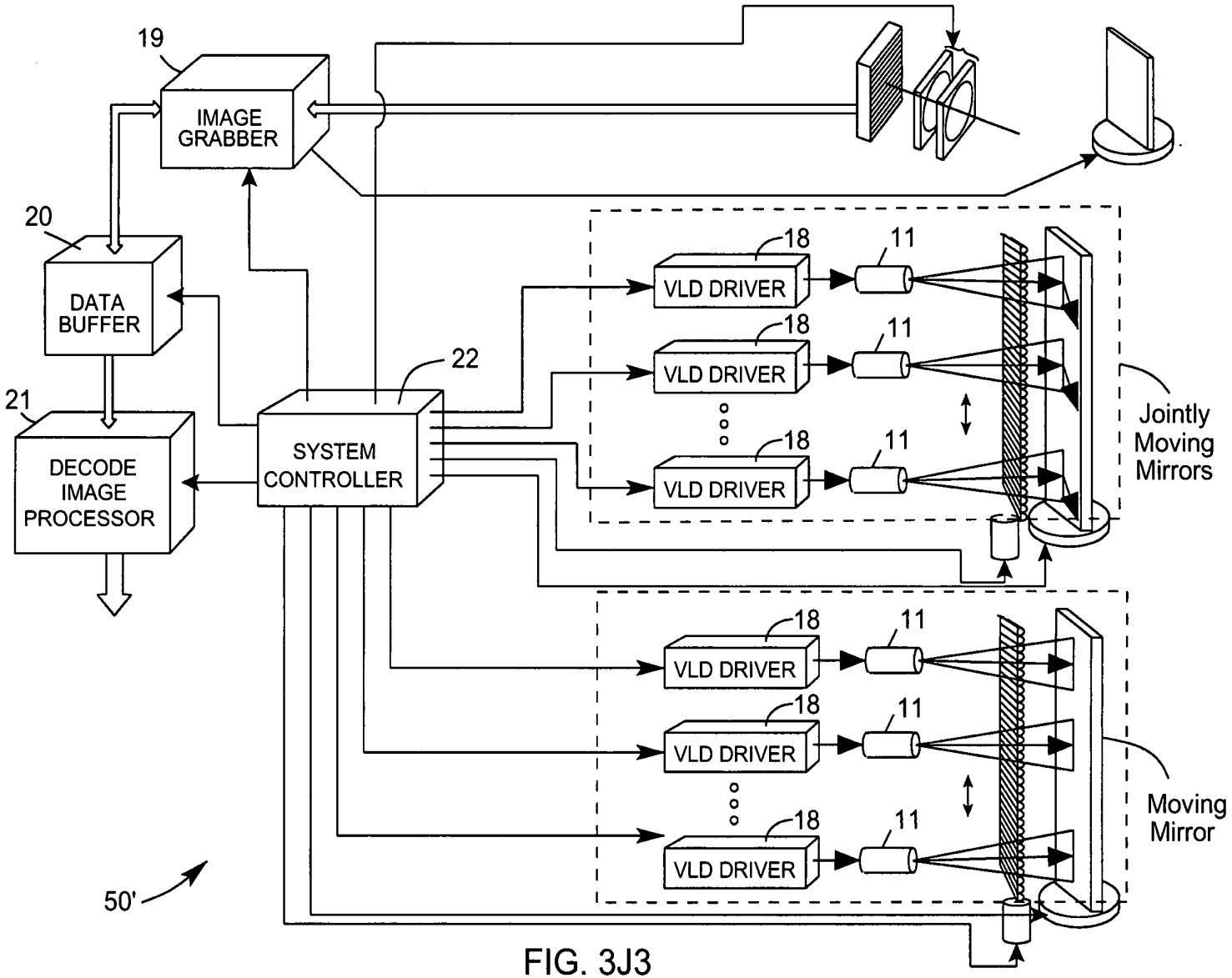

19
IMAGE GRABBER
20
DATA BUFFER
21
DECODE IMAGE PROCESSOR
22
SYSTEM CONTROLLER
18
11
VLD DRIVER
Jointly Moving Mirrors
Moving Mirror
50'

FIG. 3J3

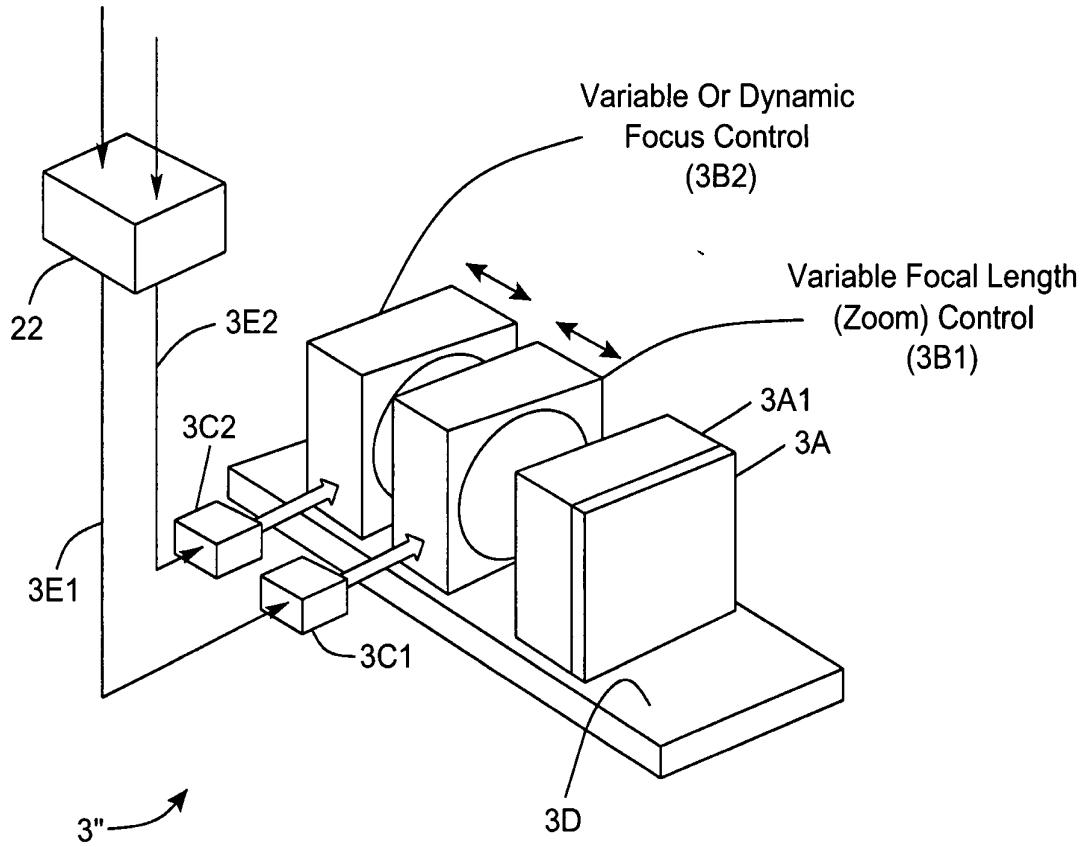

Variable Or Dynamic
Focus Control
(3B2)
Variable Focal Length
(Zoom) Control
(3B1)
22
3E2
3C2
3A1
3A
3E1
3C1
3"
3D

FIG. 3J4

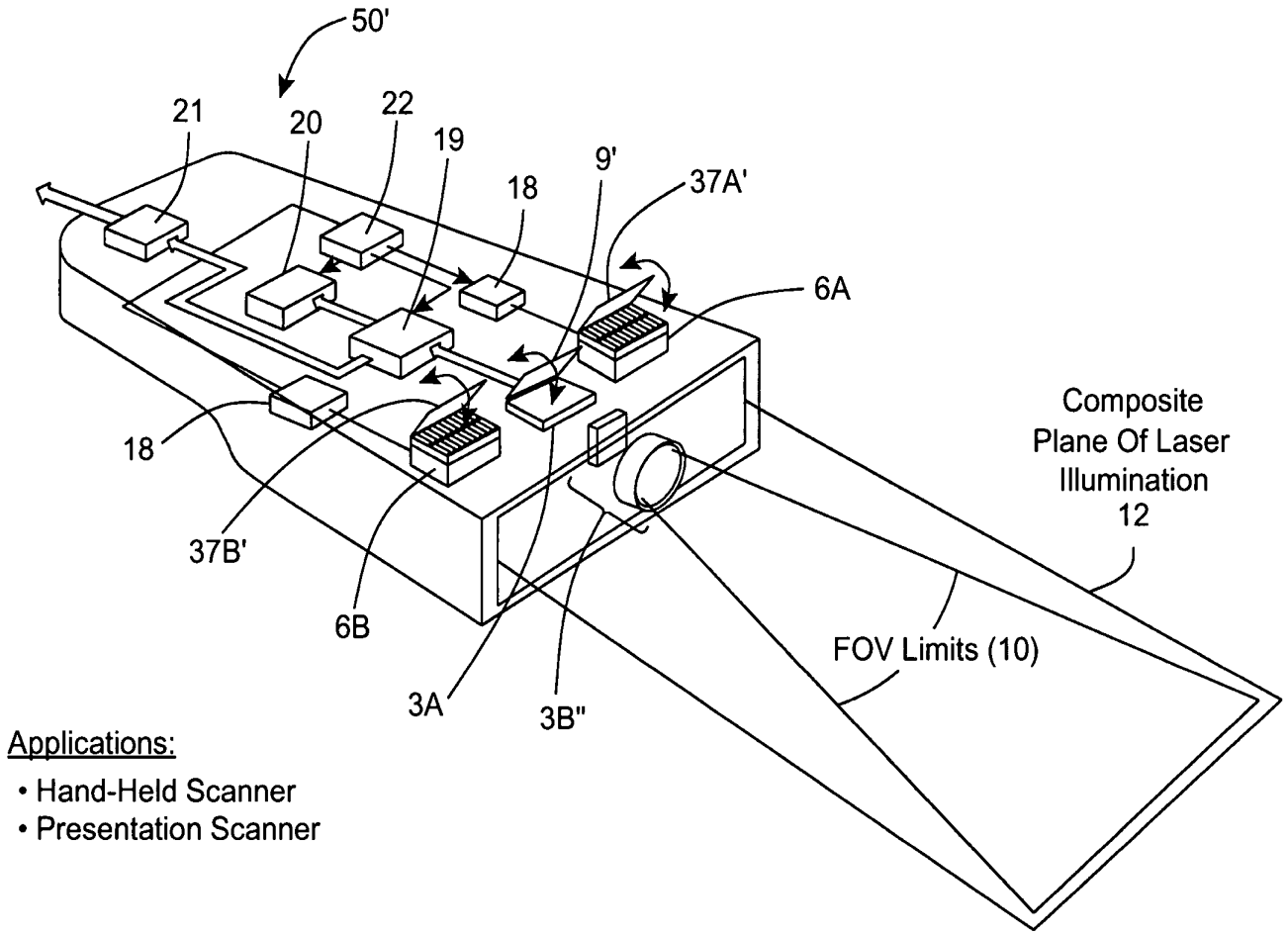
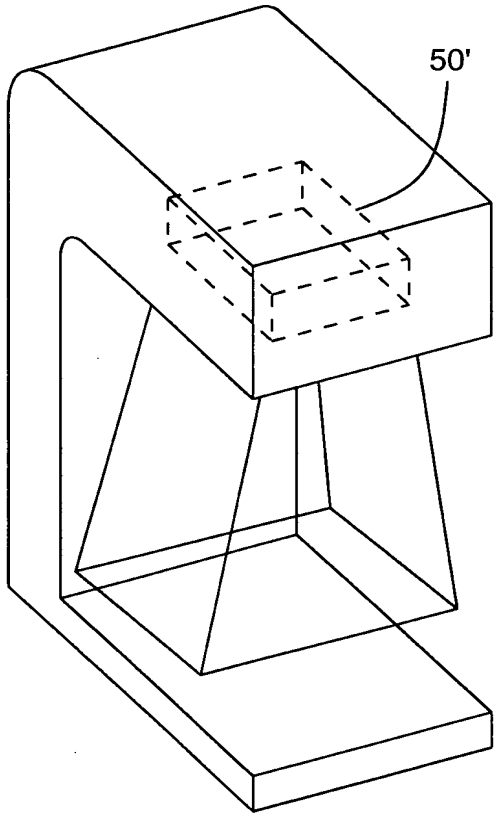

50'
21
20
22
19
18
9'
37A'
6A
18
37B'
6B
3A
3B"
Composite
Plane Of Laser
Illumination
12
FOV Limits (10)
Applications:
• Hand-Held Scanner
• Presentation Scanner

FIG. 3J5



2-D Hold-under Scanner

FIG. 3J6

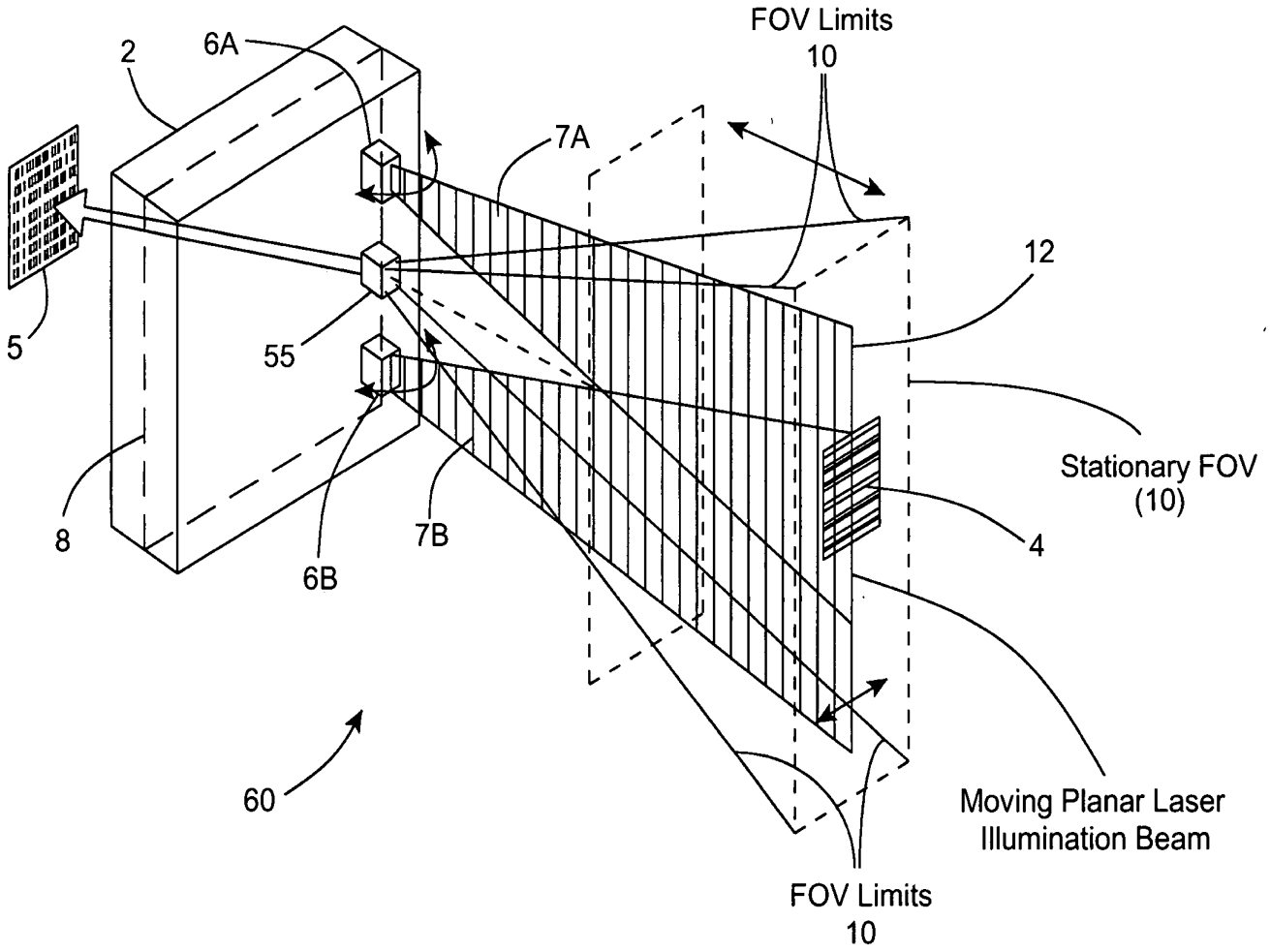

FOV Limits
10
2
6A
7A
12
5
55
Stationary FOV
(10)
8
6B
7B
4
60
Moving Planar Laser
Illumination Beam
FOV Limits
10

FIG. 4A

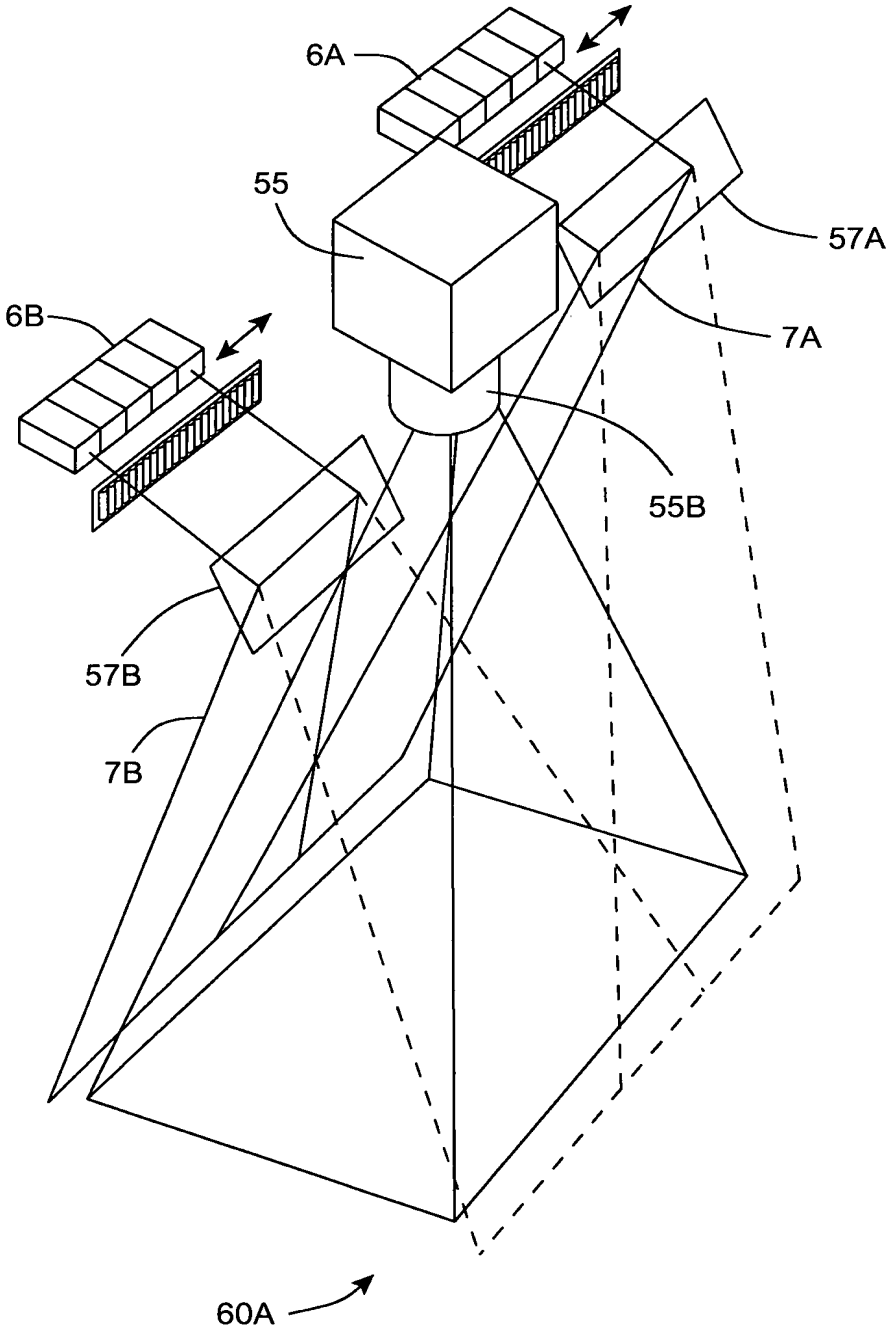


FIG. 4B1

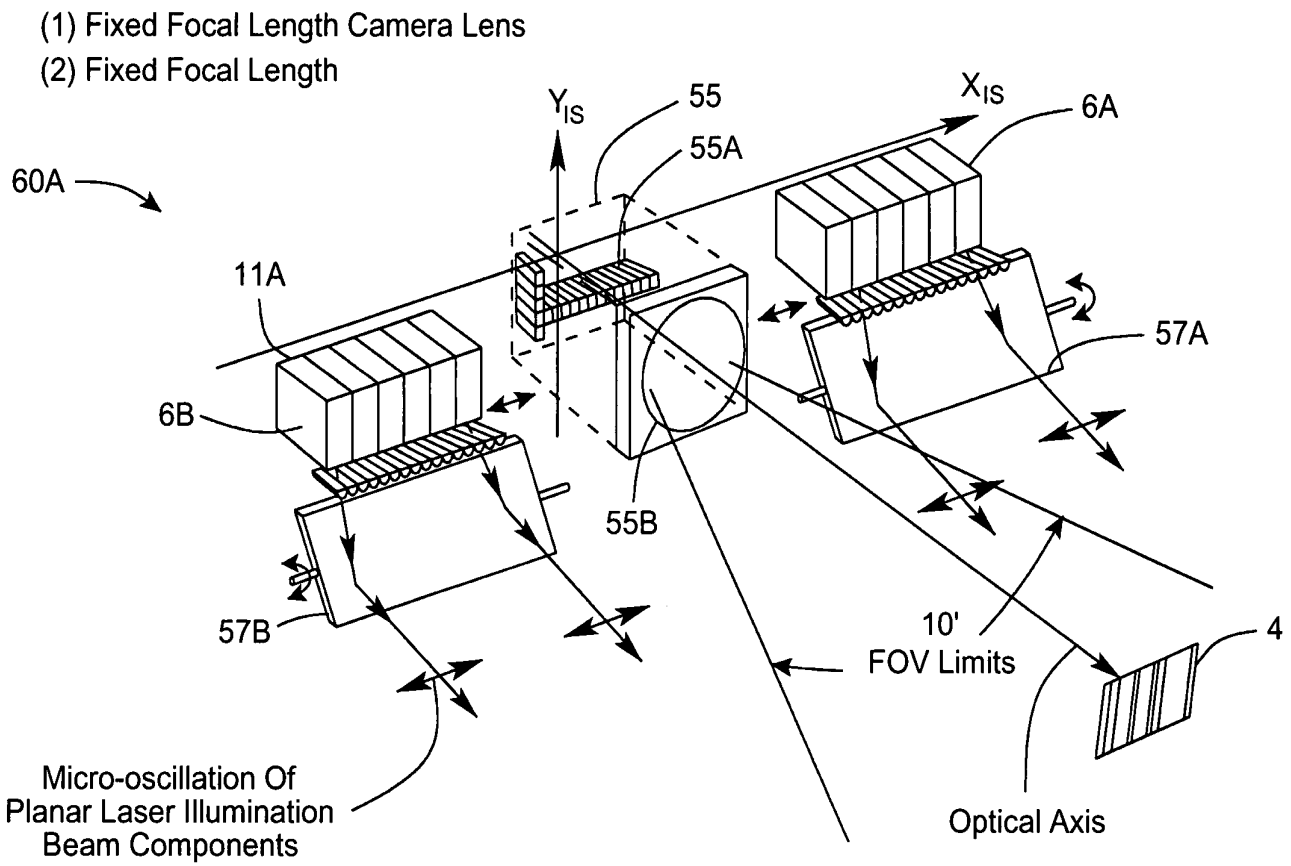

(1) Fixed Focal Length Camera Lens
(2) Fixed Focal Length
60A
Y_{IS}
55
55A
X_{IS}
6A
11A
57A
6B
55B
57B
10'
FOV Limits
4
Micro-oscillation Of
Planar Laser Illumination
Beam Components
Optical Axis

FIG. 4B2

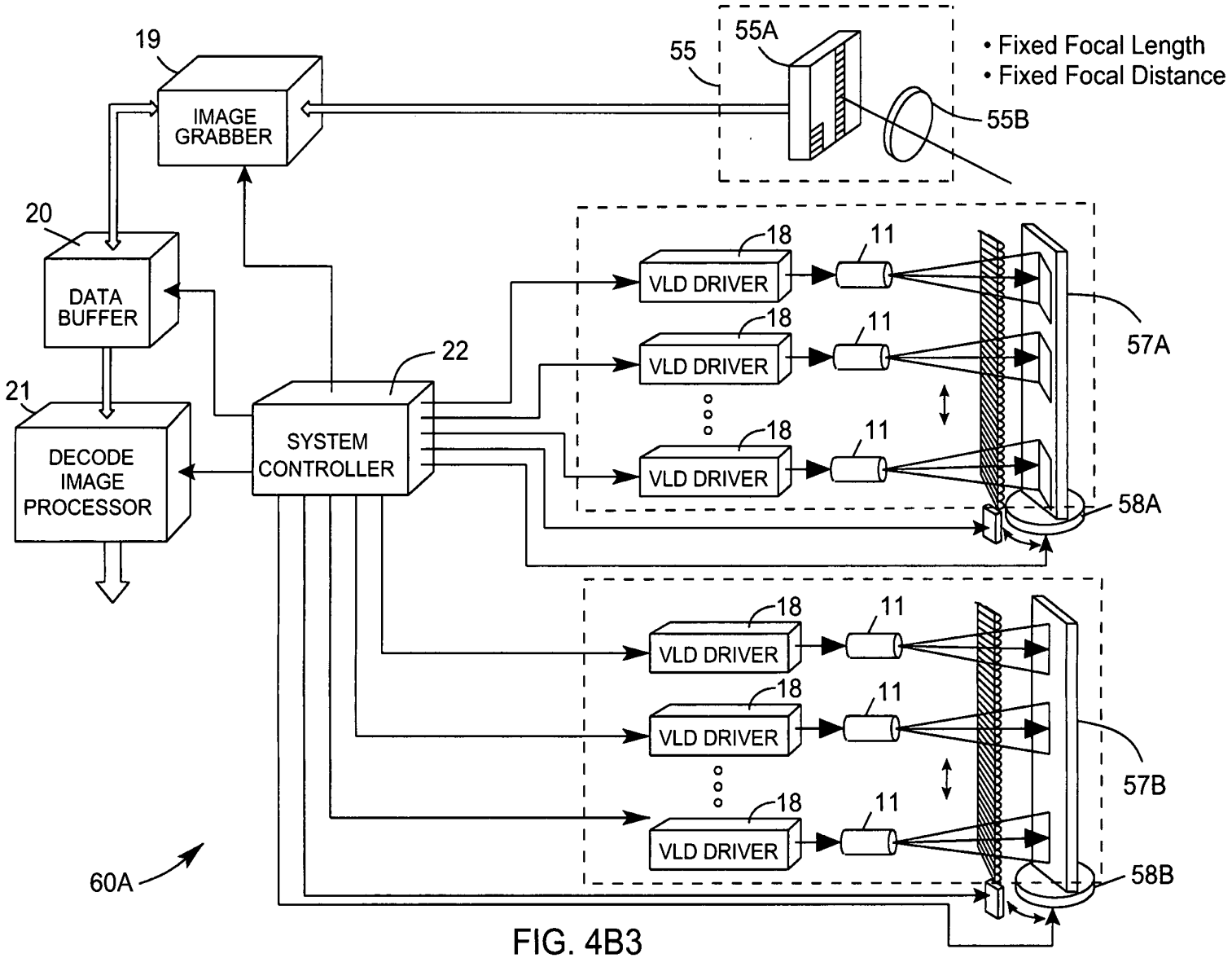

19
IMAGE GRABBER
55
55A
55B
• Fixed Focal Length
• Fixed Focal Distance
20
DATA BUFFER
21
DECODE IMAGE PROCESSOR
22
SYSTEM CONTROLLER
18
11
VLD DRIVER
57A
58A
57B
58B
60A

FIG. 4B3

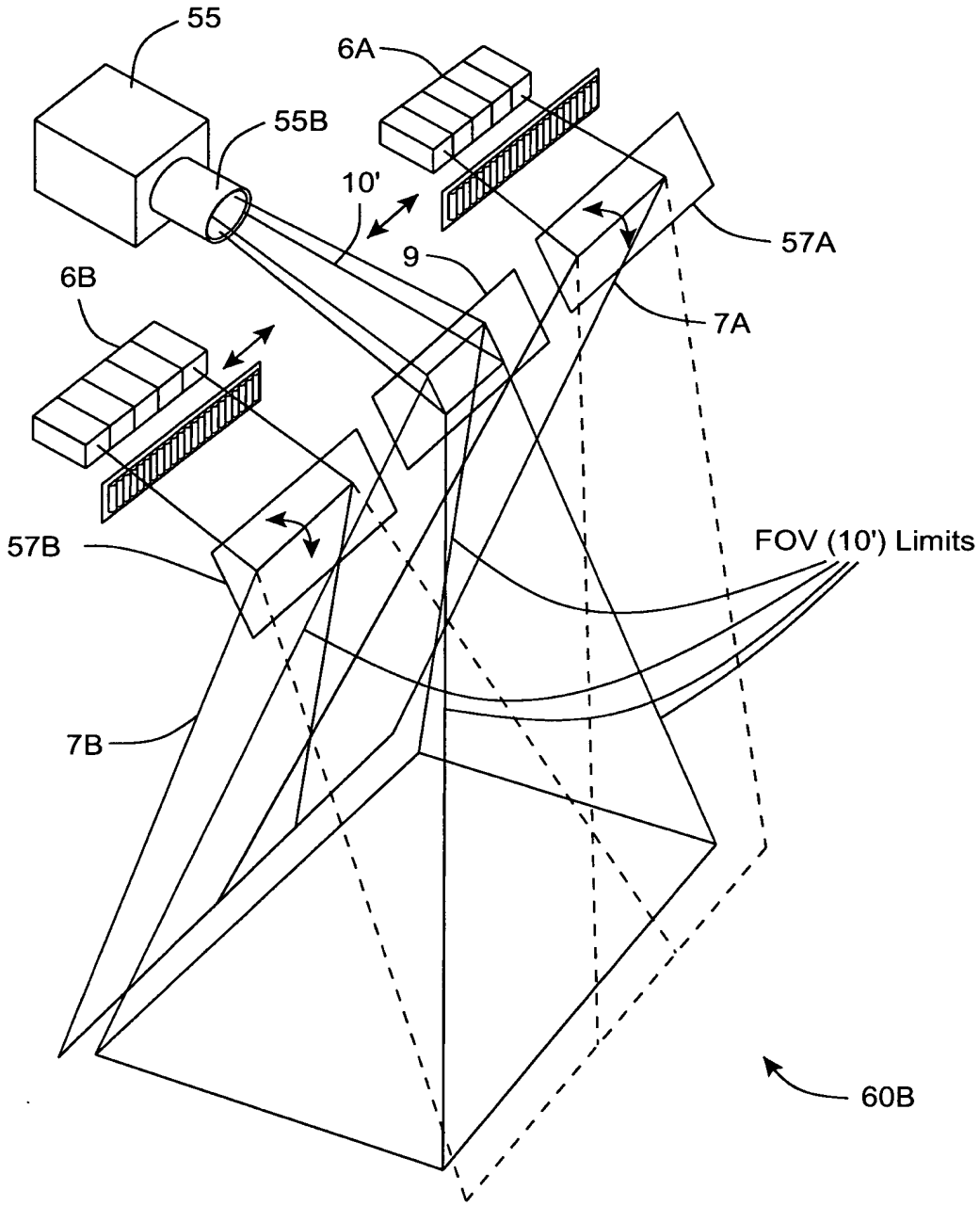


FIG. 4C1

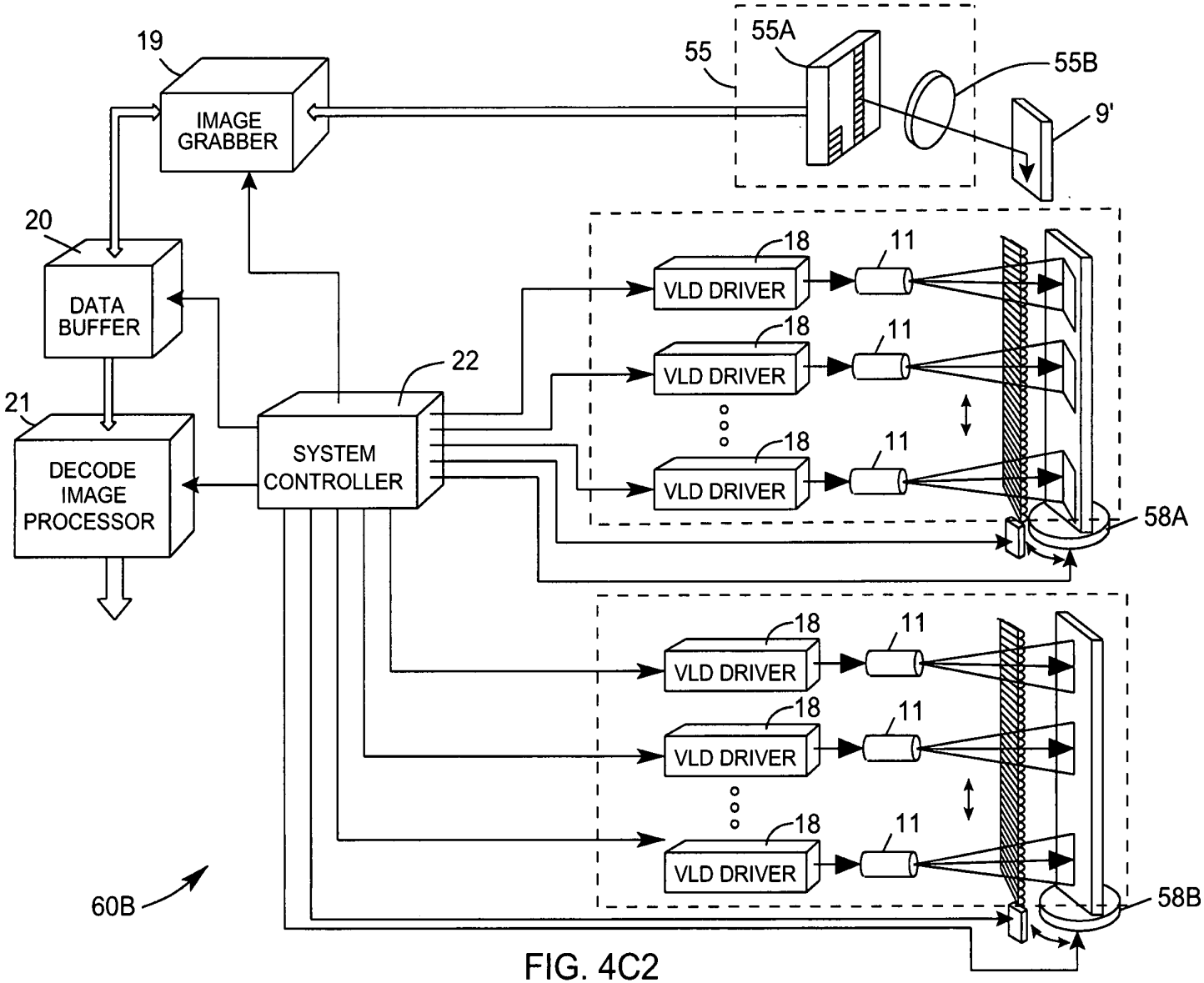
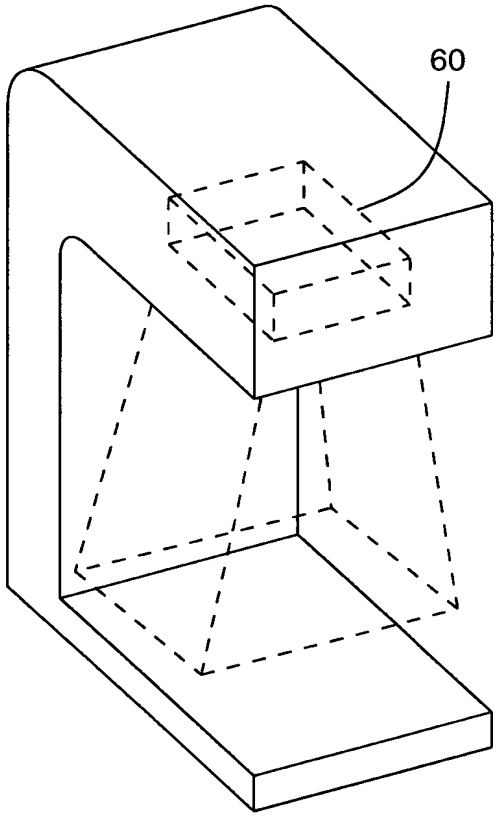

19
IMAGE GRABBER
55
55A
55B
9'
20
DATA BUFFER
21
DECODE IMAGE PROCESSOR
22
SYSTEM CONTROLLER
18
11
VLD DRIVER
58A
58B
60B

FIG. 4C2



2-D Hold-under Scanner

FIG. 4D

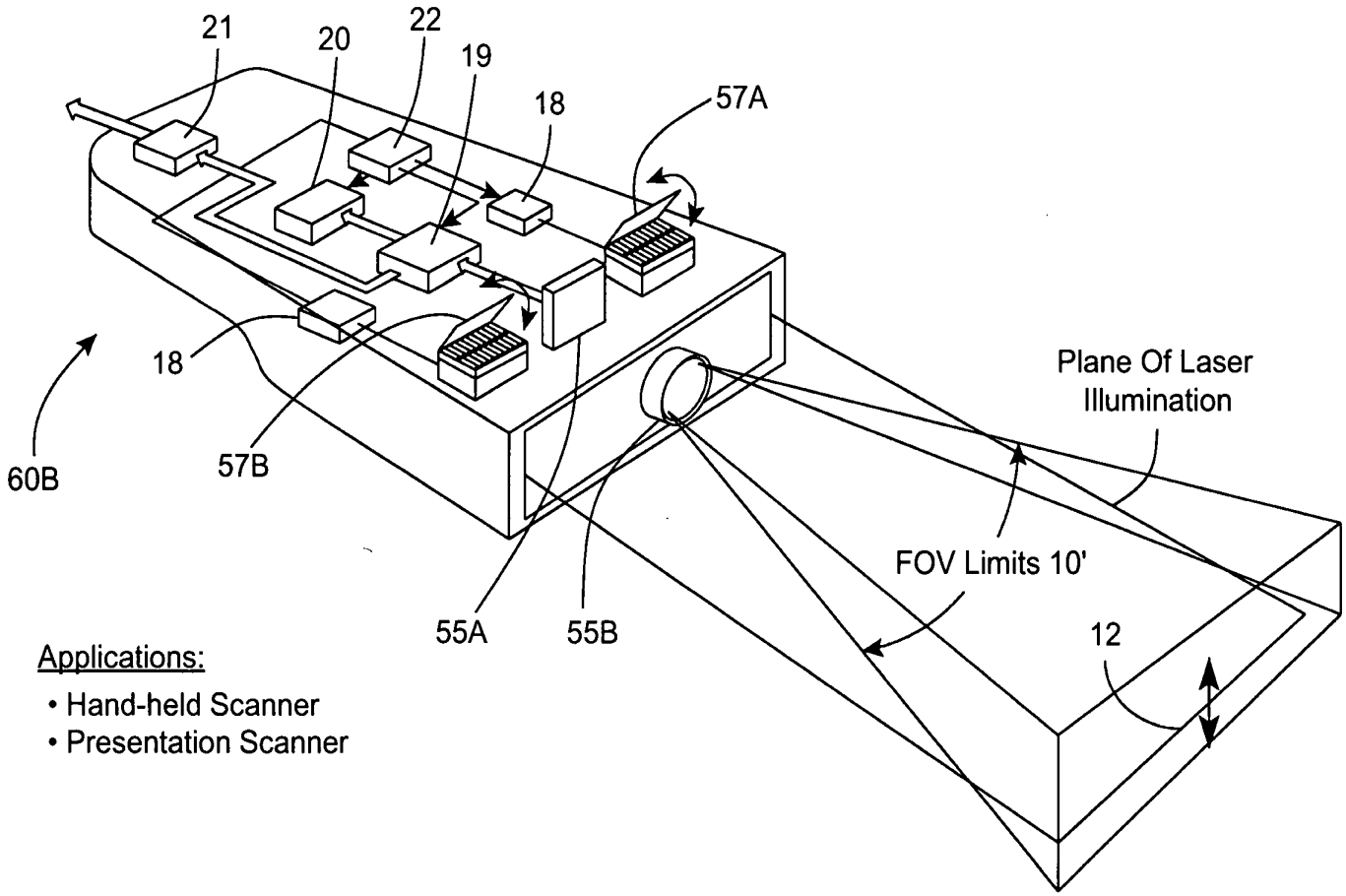

21
20
22
19
18
57A
18
60B
57B
55A
55B
Plane Of Laser Illumination
FOV Limits 10'
12
Applications:
• Hand-held Scanner
• Presentation Scanner

FIG. 4E

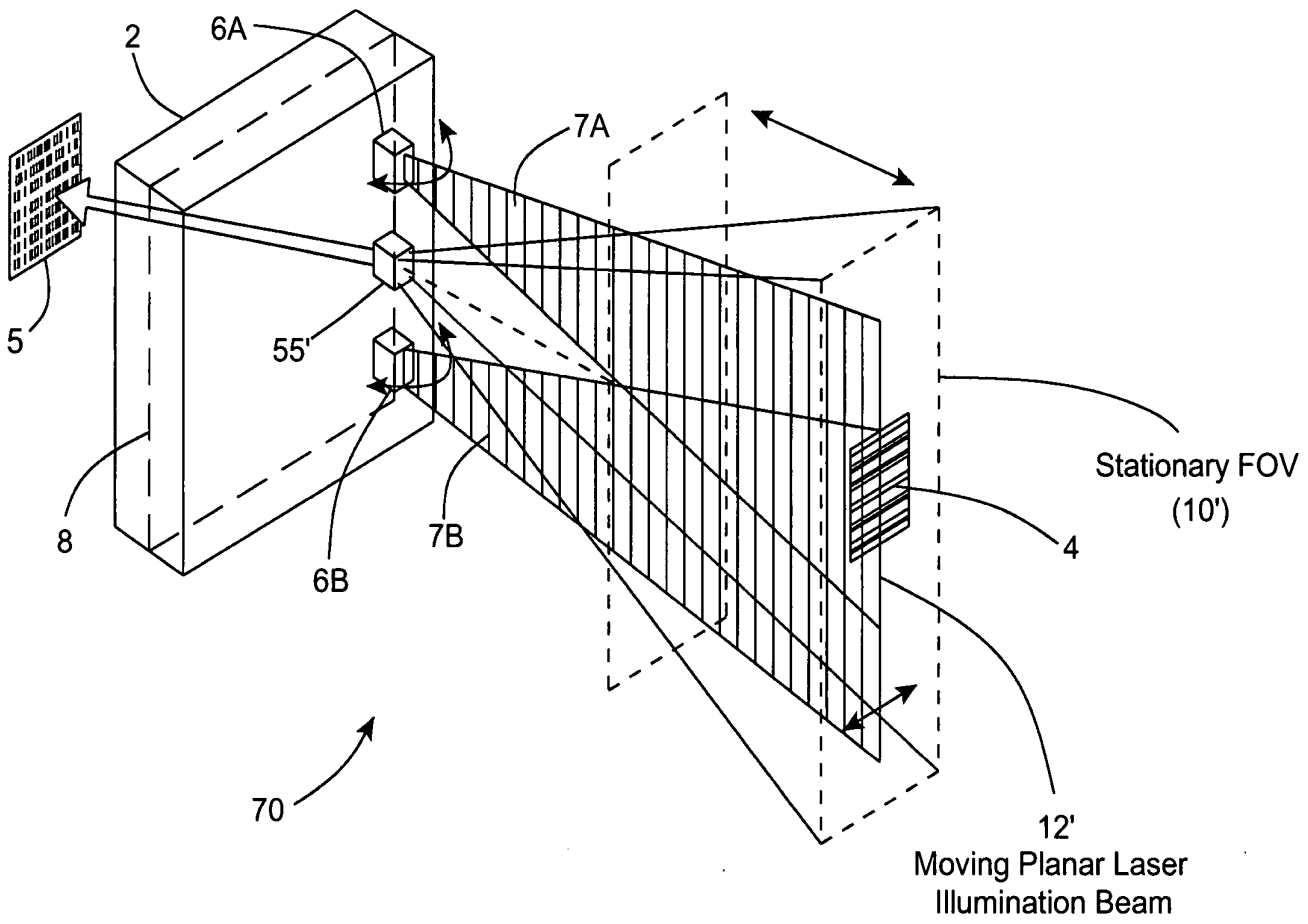

2
6A
7A
5
55'
8
6B
7B
4
Stationary FOV
(10')
70
12'
Moving Planar Laser
Illumination Beam

FIG. 5A

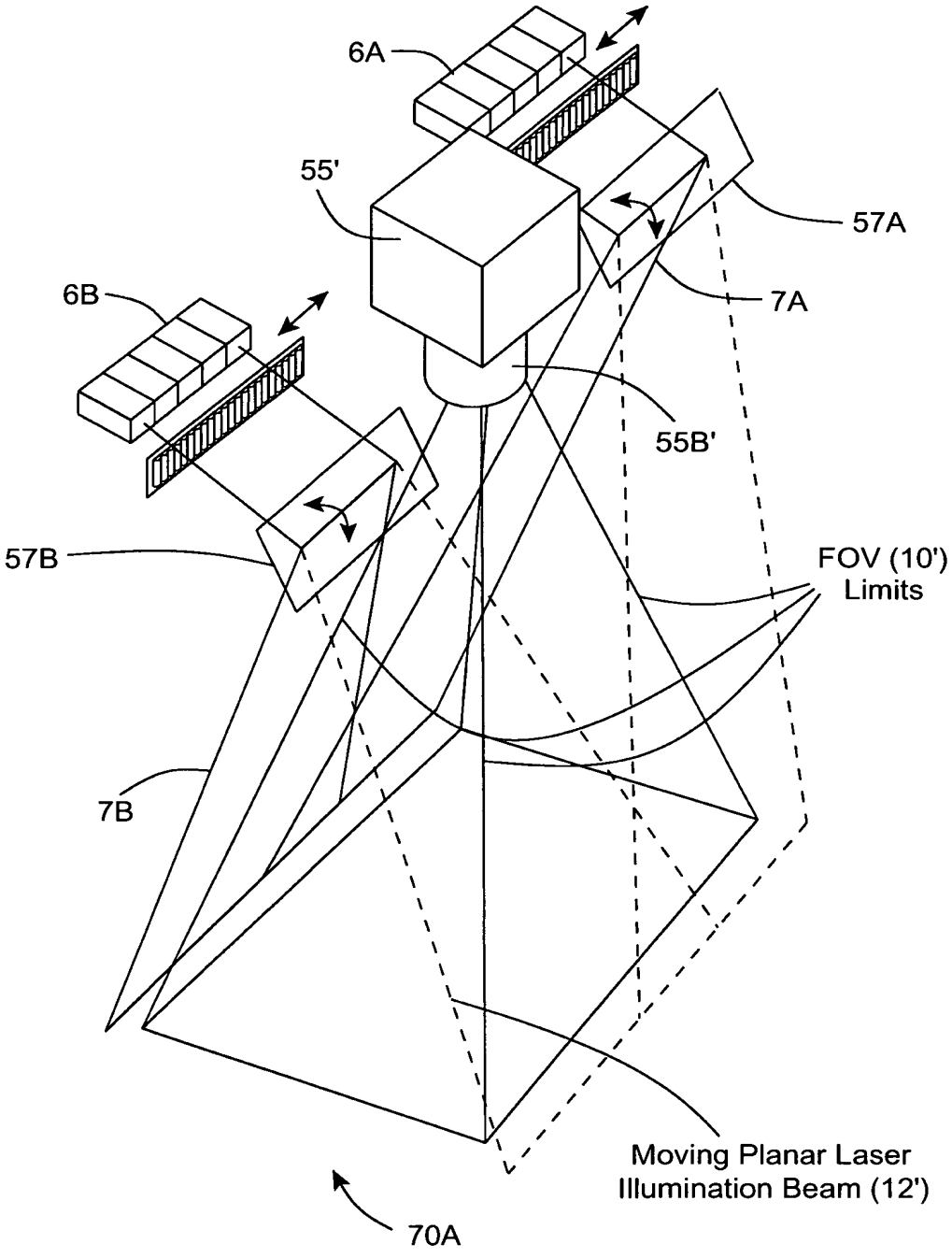

6A
55'
57A
7A
6B
55B'
57B
FOV (10')
Limits
7B
Moving Planar Laser
Illumination Beam (12')
70A

FIG. 5B1

(1) Fixed Focal Length Camera Lens
(2) Variable Focal Distance

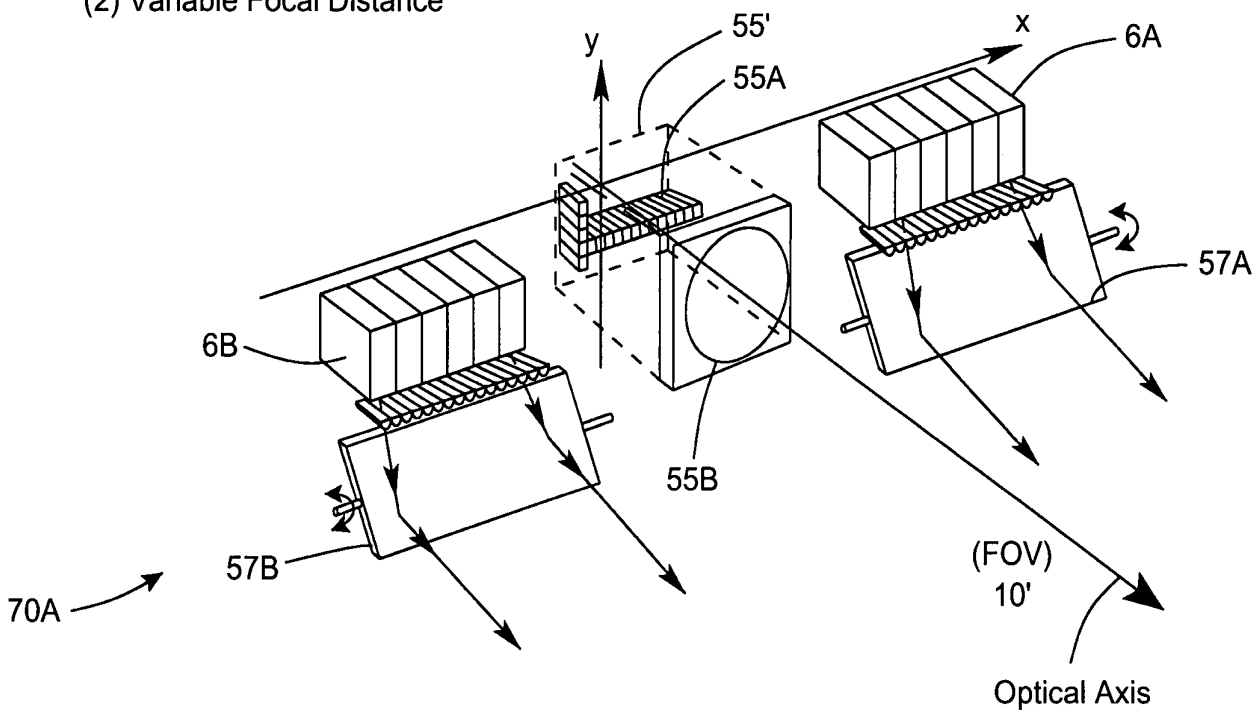


FIG. 5B2

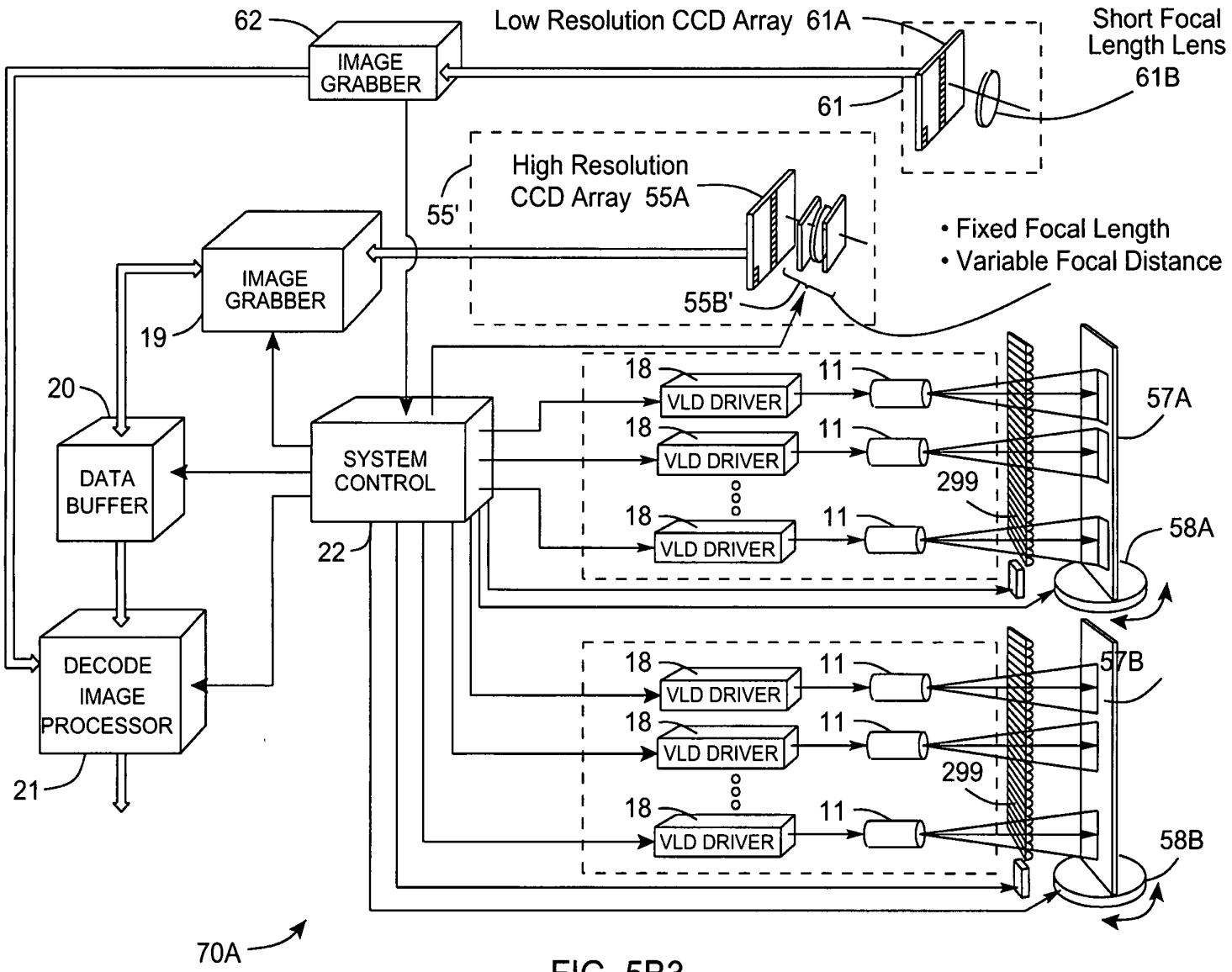

62
IMAGE GRABBER
Low Resolution CCD Array 61A
Short Focal Length Lens 61B
61
High Resolution CCD Array 55A
55'
• Fixed Focal Length
• Variable Focal Distance
55B'
IMAGE GRABBER
19
20
DATA BUFFER
SYSTEM CONTROL
22
18
VLD DRIVER
11
299
57A
58A
57B
58B
DECODE IMAGE PROCESSOR
21
70A

FIG. 5B3

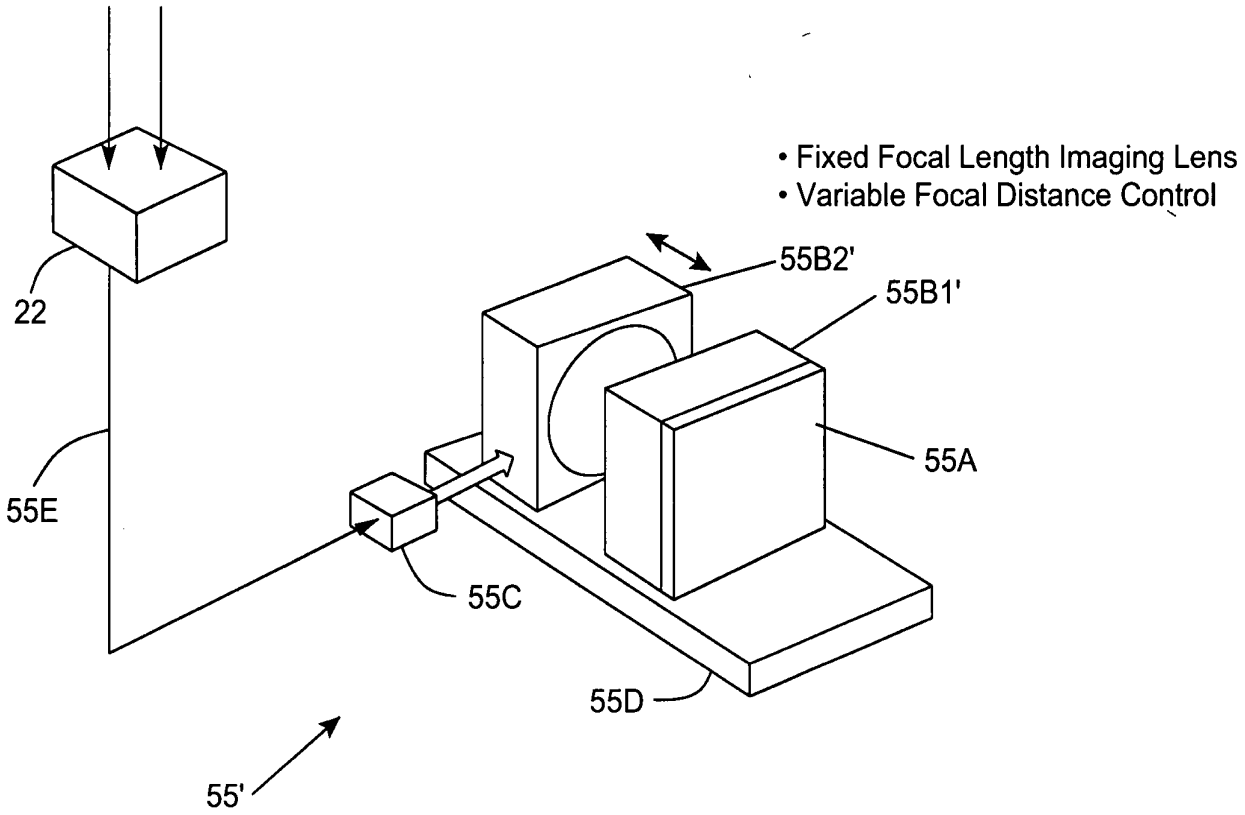

• Fixed Focal Length Imaging Lens
• Variable Focal Distance Control
22
55E
55B2'
55B1'
55A
55C
55D
55'

FIG. 5B4

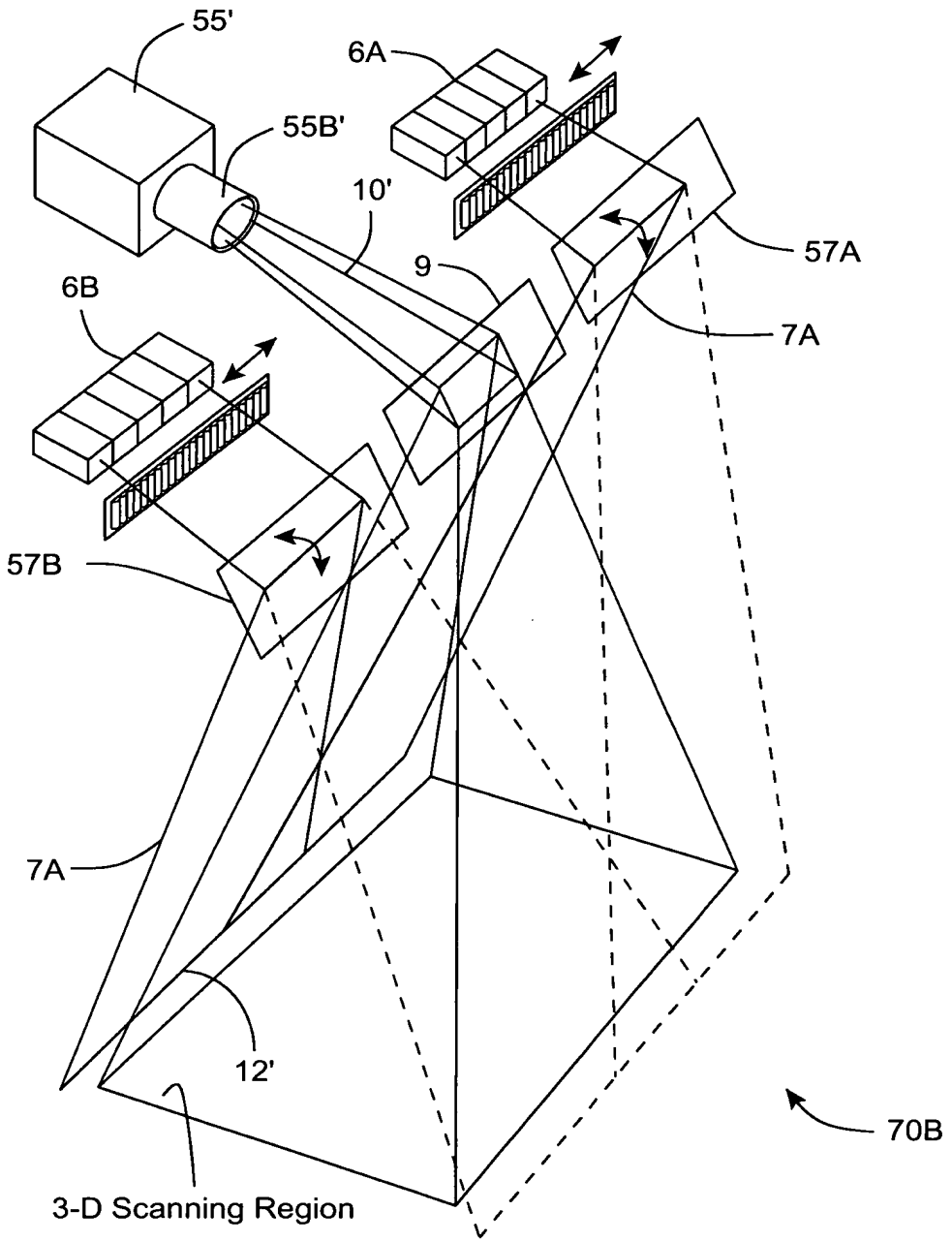


FIG. 5C1

(1) Variable Focal Length Camera Lens
(2) Fixed Focal Distance

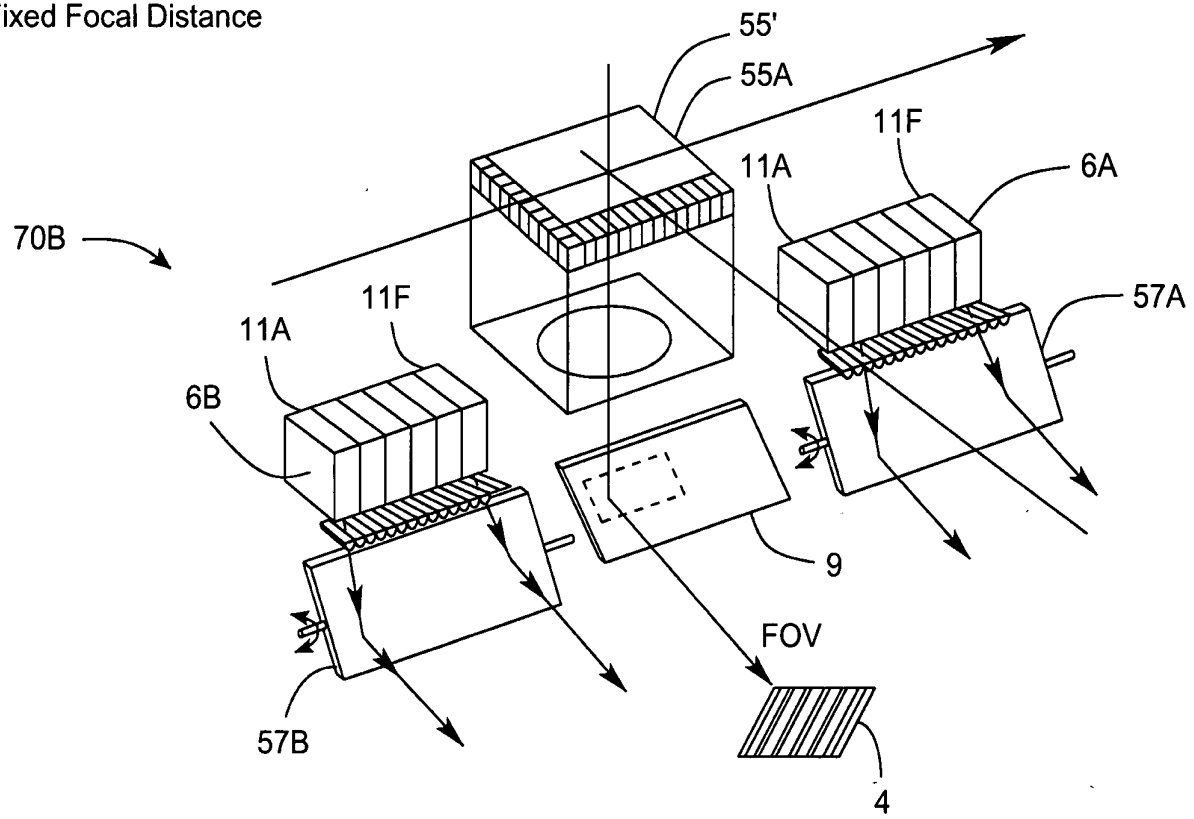


FIG. 5C2

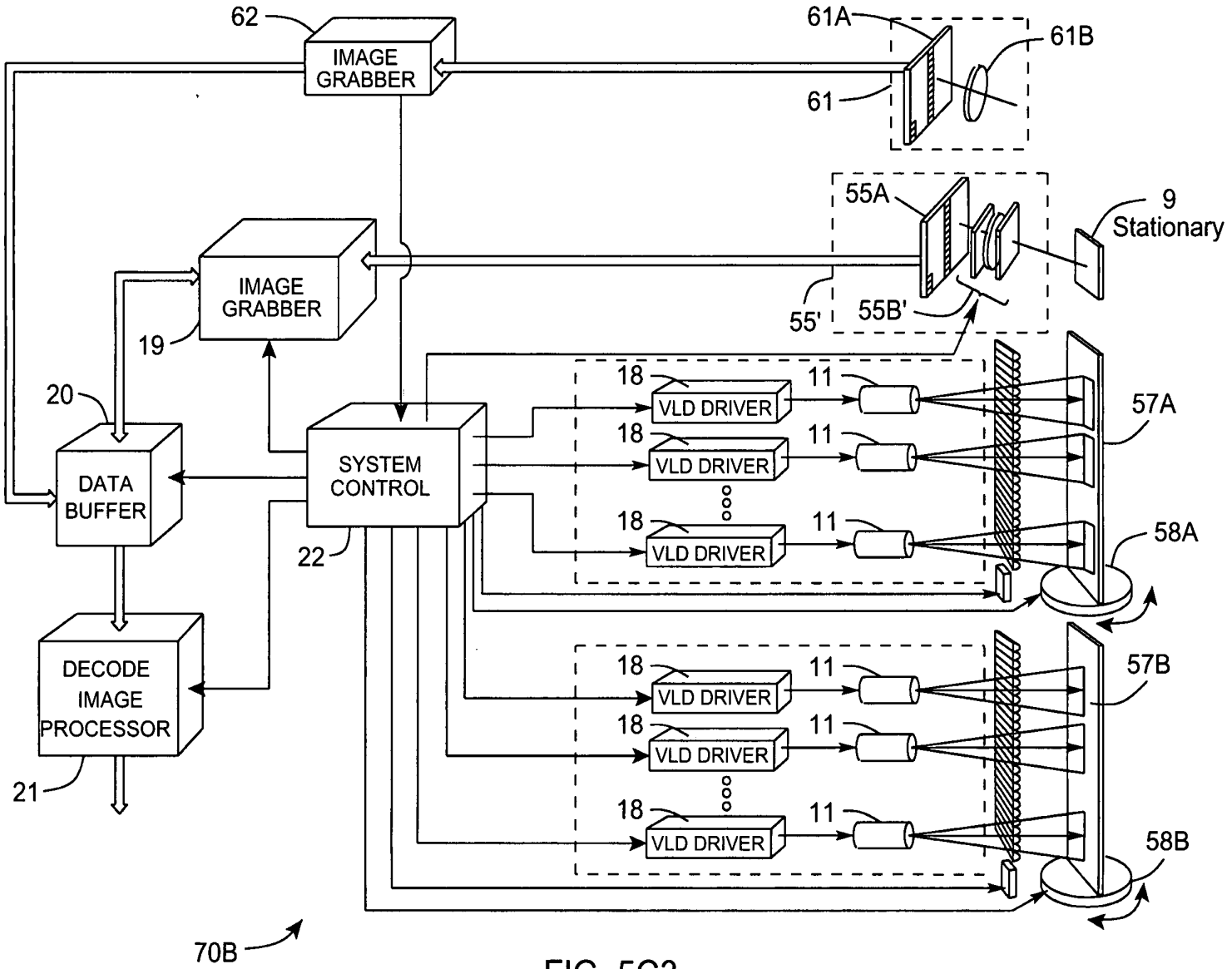

62
IMAGE GRABBER
61A
61B
61
55A
9
Stationary
IMAGE GRABBER
19
55'
55B'
20
18
11
VLD DRIVER
57A
DATA BUFFER
SYSTEM CONTROL
22
58A
DECODE IMAGE PROCESSOR
57B
21
58B
70B

FIG. 5C3

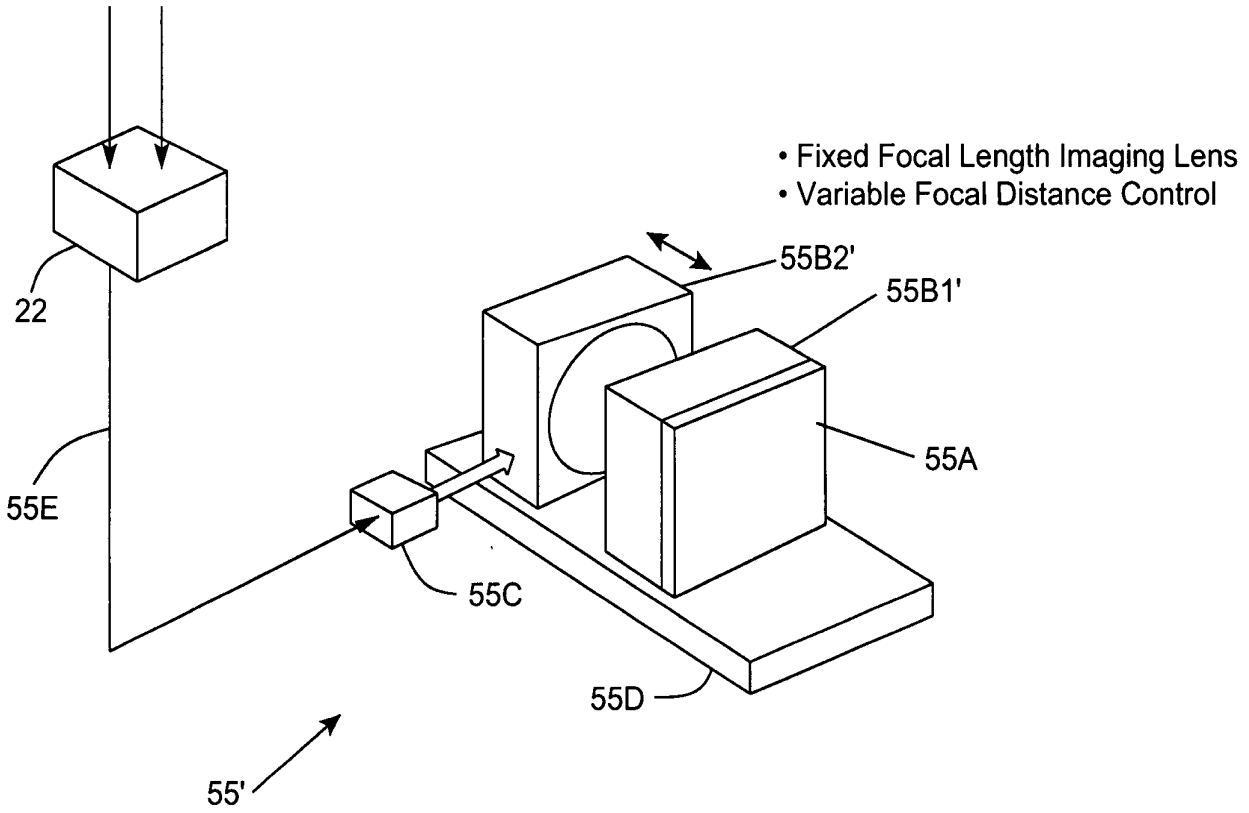

• Fixed Focal Length Imaging Lens
• Variable Focal Distance Control
22
55E
55B2'
55B1'
55A
55C
55D
55'

FIG. 5C4

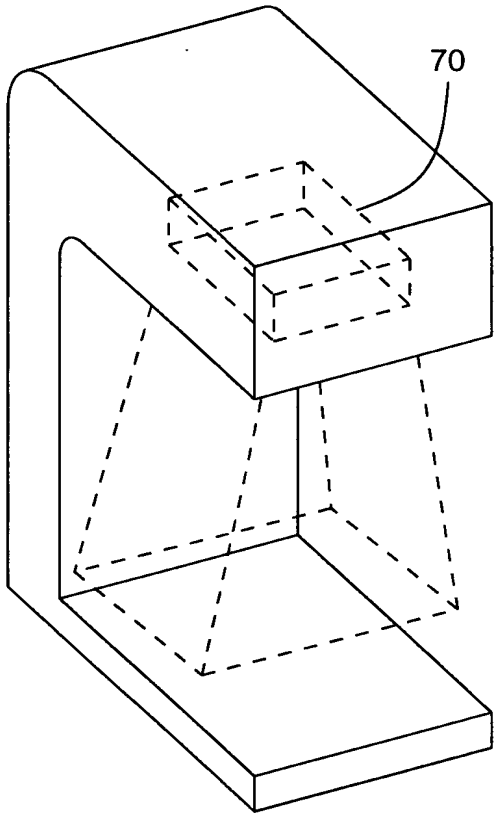


FIG. 5D

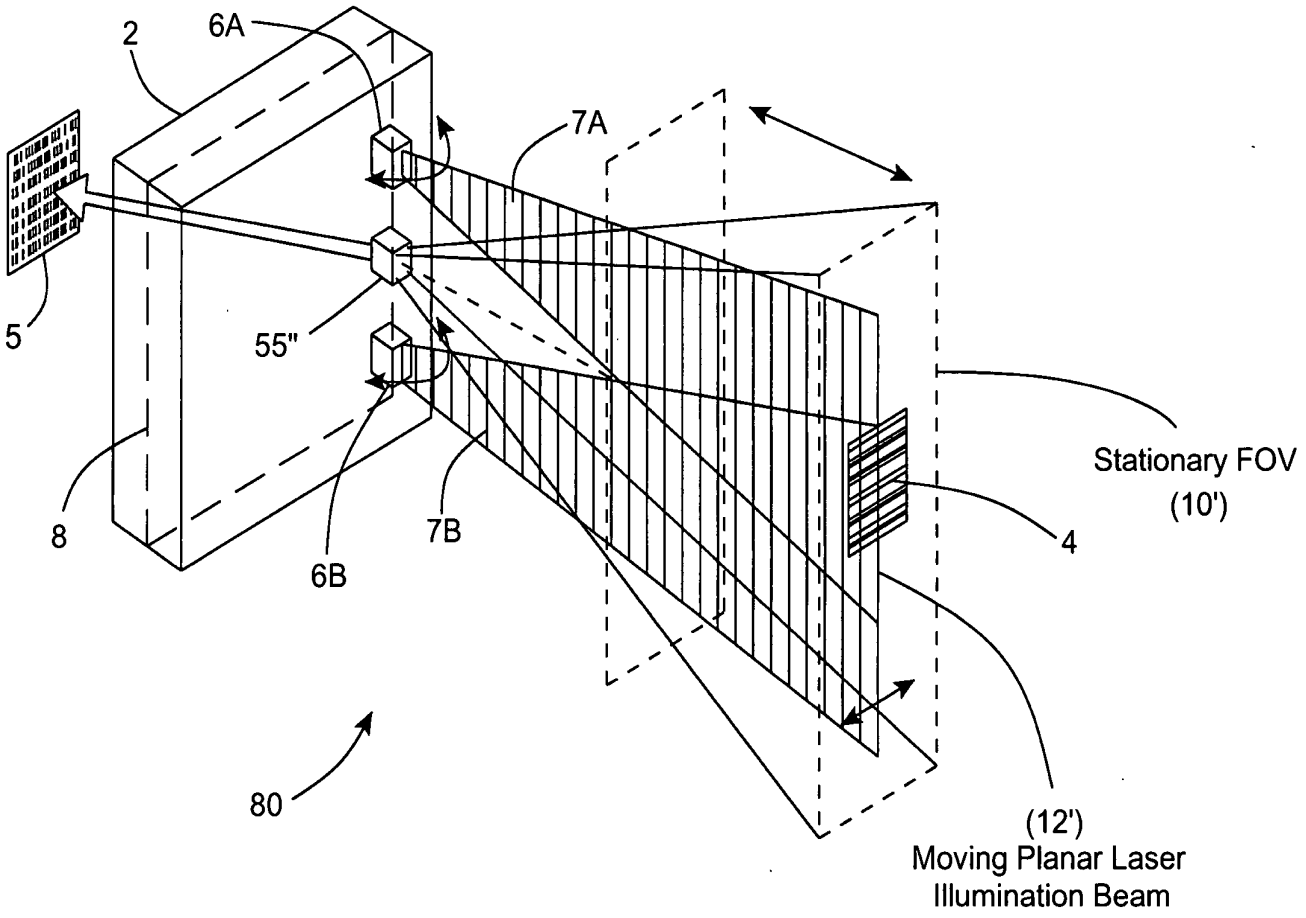

2
6A
7A
5
55"
8
6B
7B
4
Stationary FOV
(10')
80
(12')
Moving Planar Laser
Illumination Beam

FIG. 6A

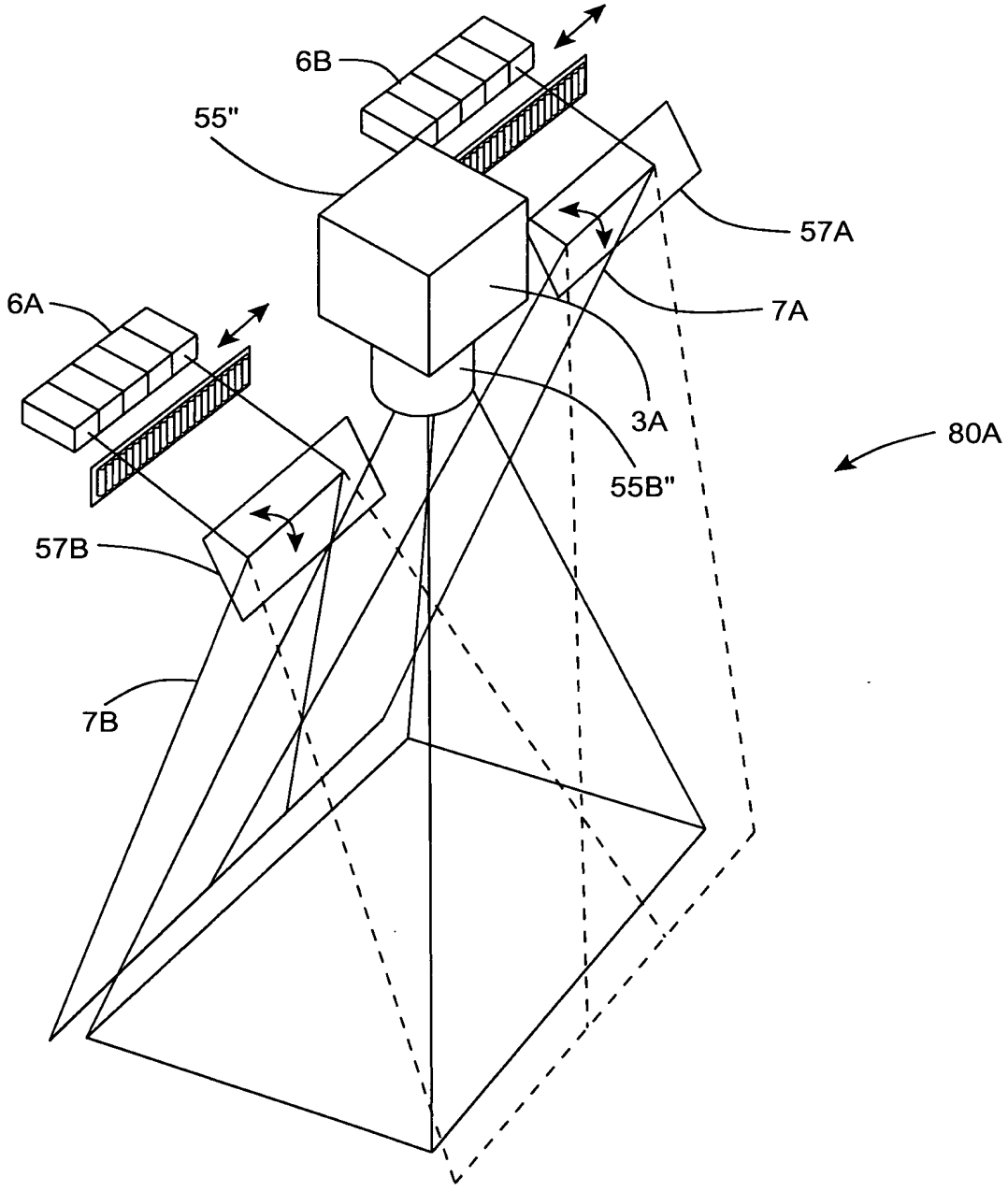


FIG. 6B1

(1) Variable Focal Length Camera Lens
(2) Variable Focal Distance

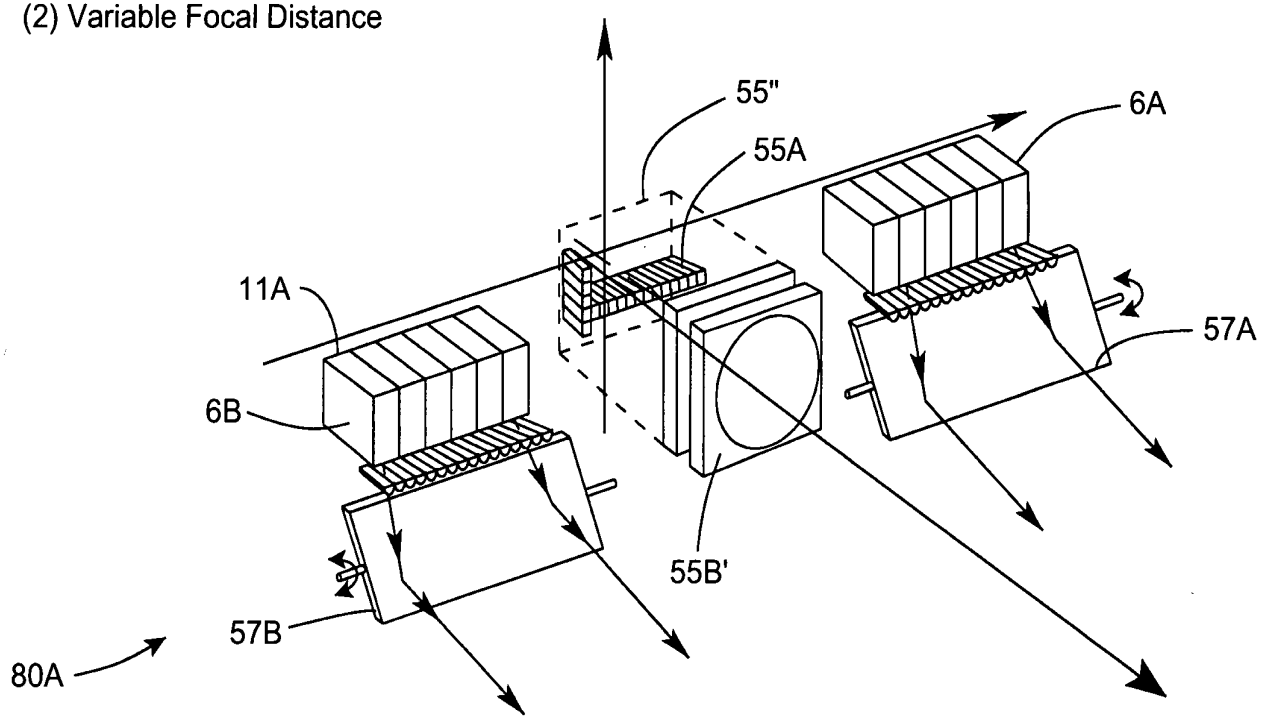


FIG. 6B2

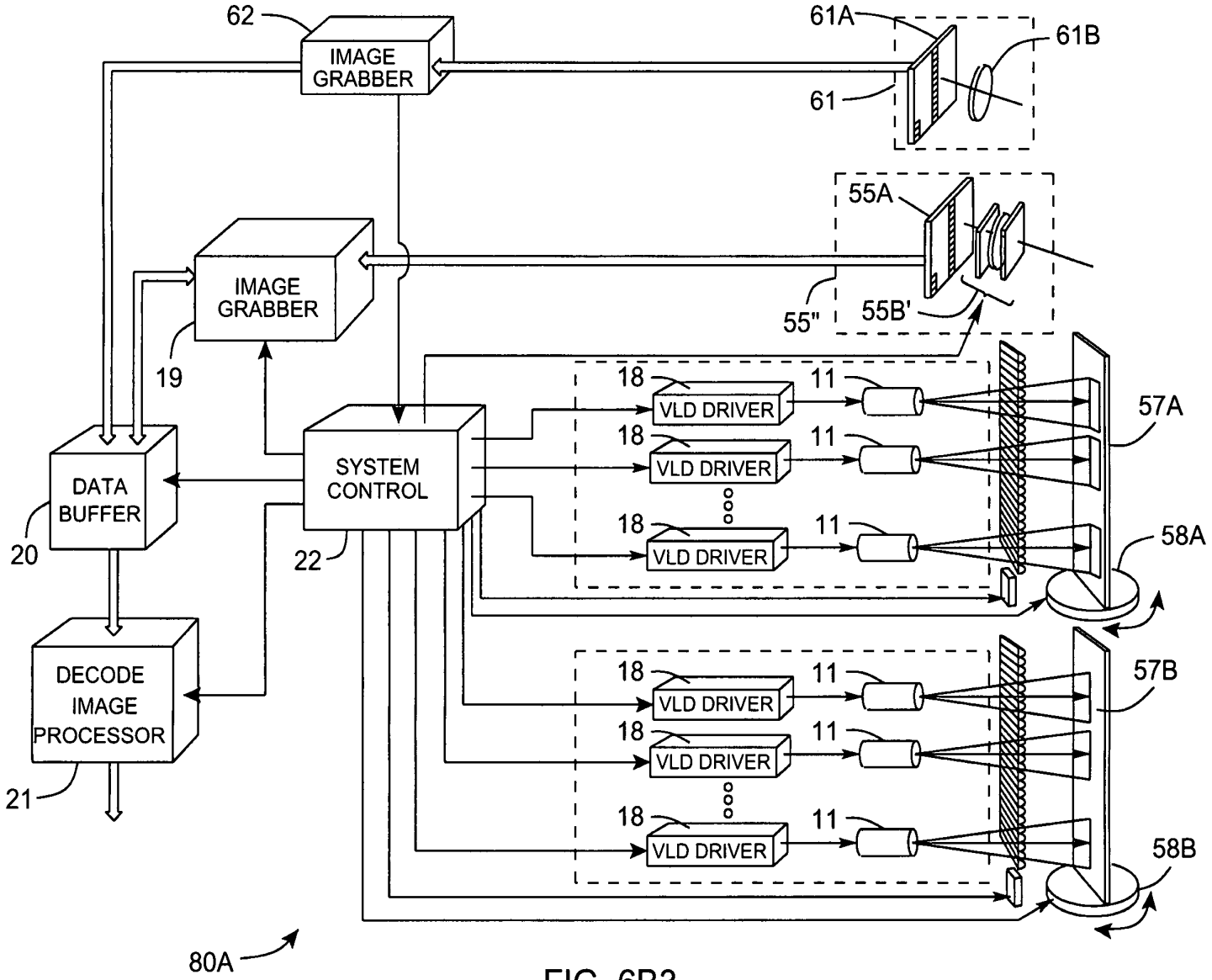

62
IMAGE GRABBER
61A
61B
61
55A
55"
55B'
IMAGE GRABBER
19
18
VLD DRIVER
11
57A
58A
DATA BUFFER
20
SYSTEM CONTROL
22
DECODE IMAGE PROCESSOR
21
57B
58B
80A

FIG. 6B3

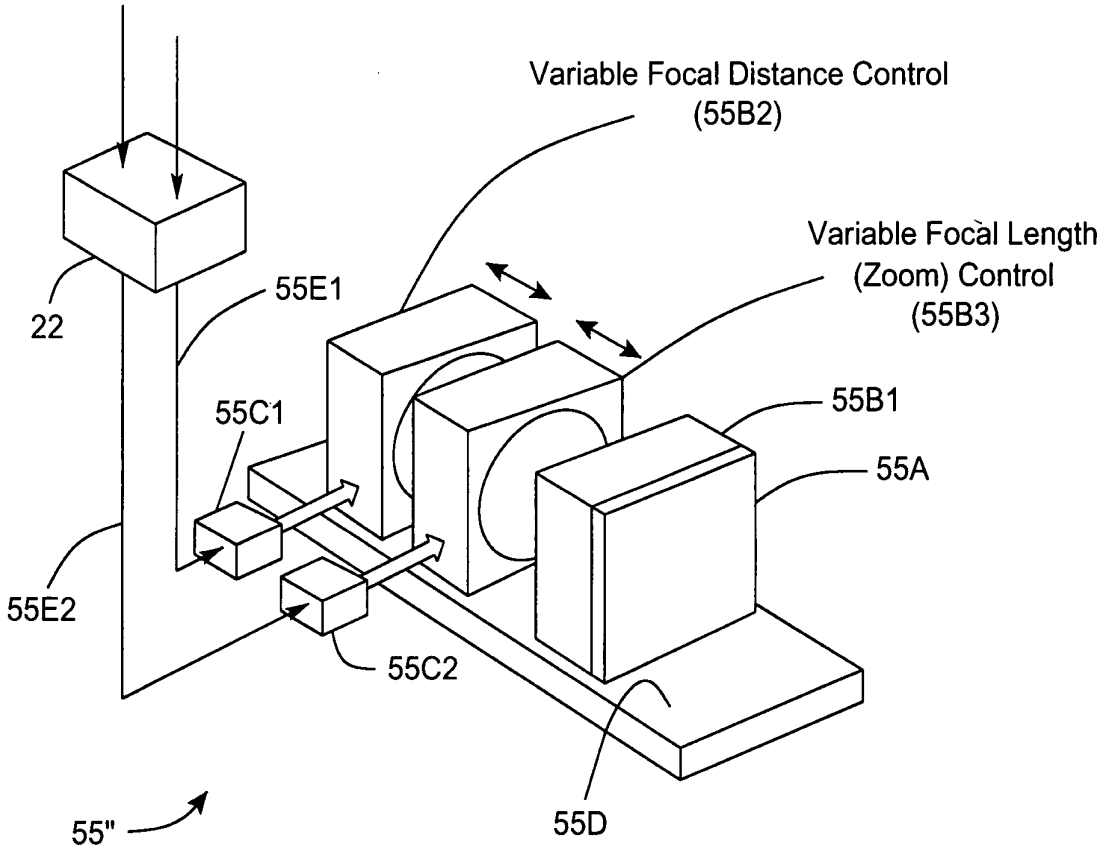

Variable Focal Distance Control
(55B2)
Variable Focal Length
(Zoom) Control
(55B3)
22
55E1
55C1
55B1
55A
55E2
55C2
55"
55D

FIG. 6B4

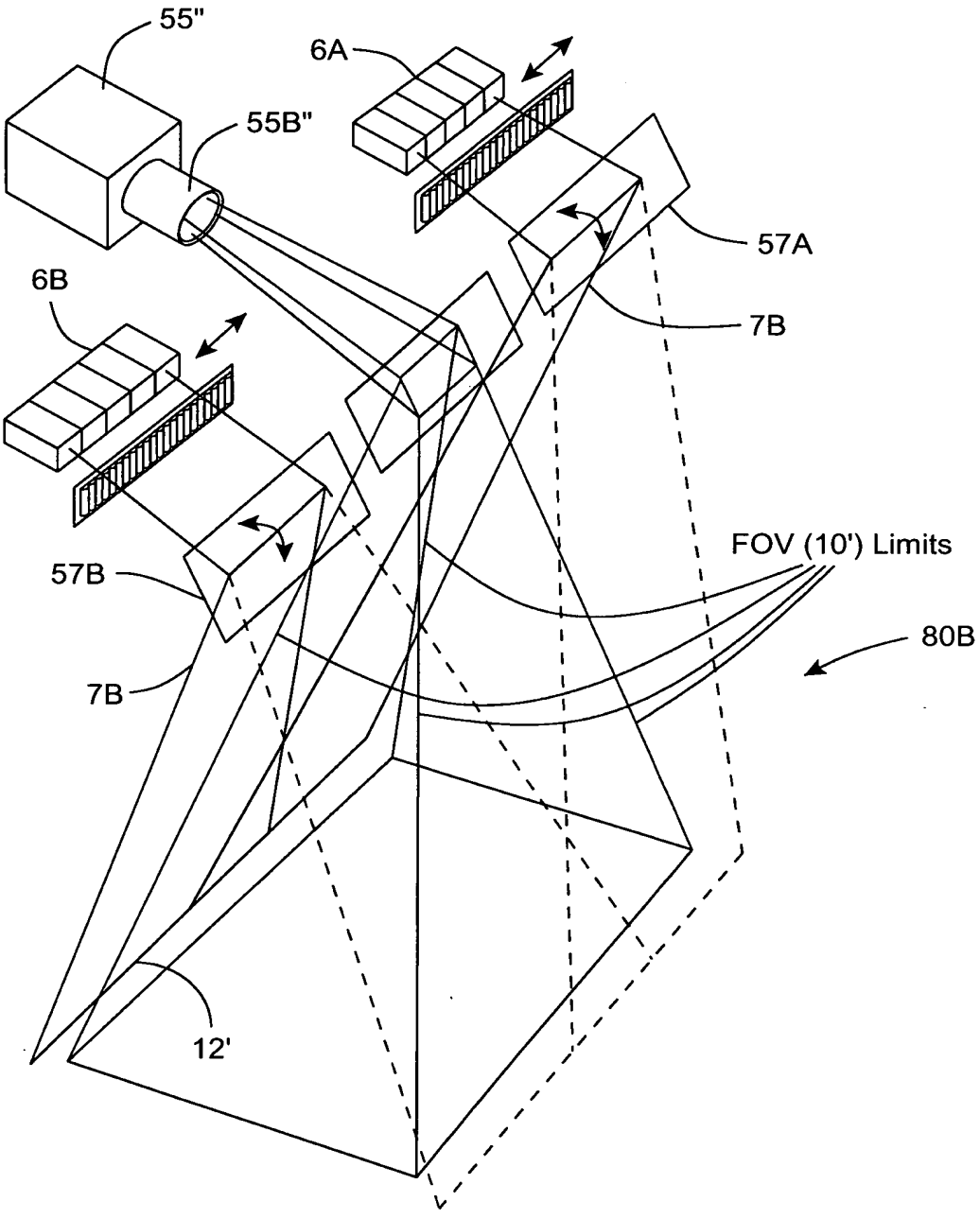


FIG. 6C1

(1) Variable Focal Length Camera Lens
(2) Variable Focal Distance

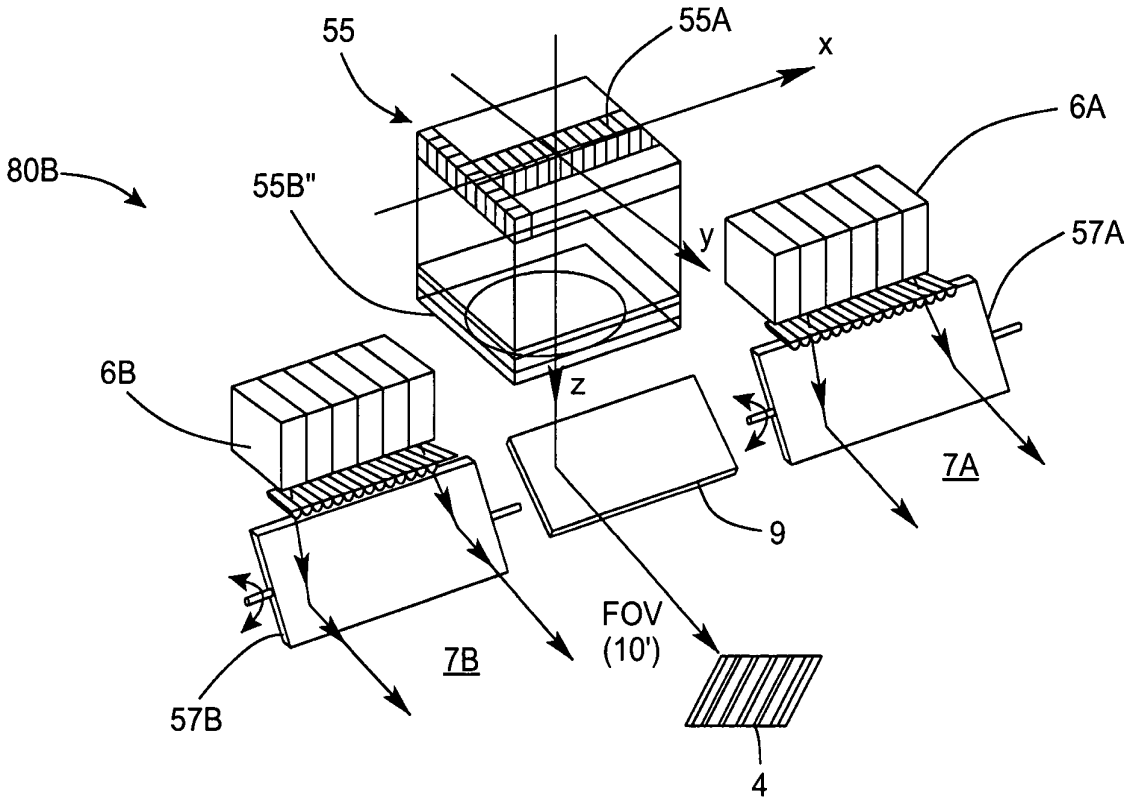


FIG. 6C2

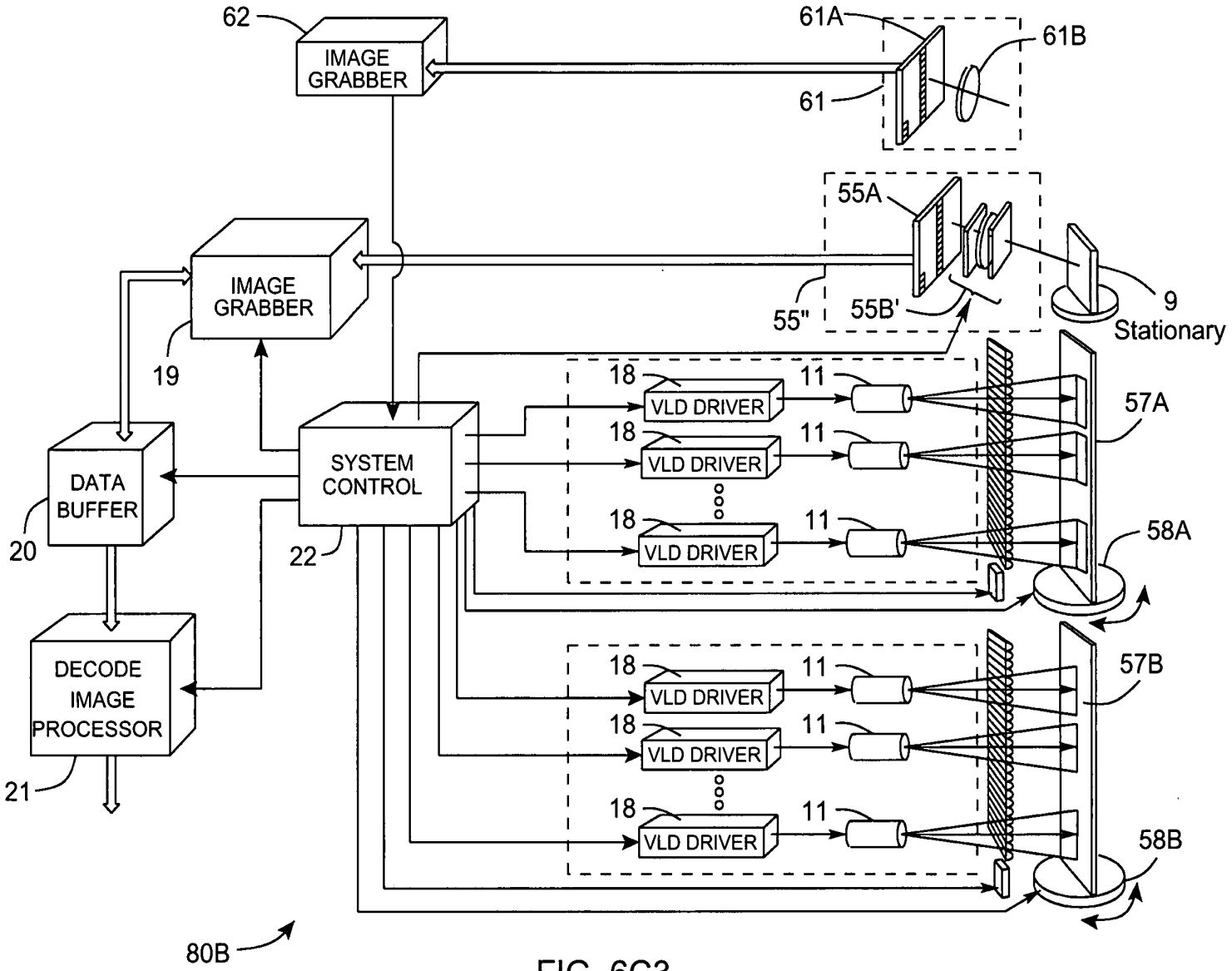

62
IMAGE GRABBER
61A
61B
61
55A
55"
55B'
9
Stationary
IMAGE GRABBER
19
DATA BUFFER
20
SYSTEM CONTROL
22
18
VLD DRIVER
11
57A
58A
DECODE IMAGE PROCESSOR
21
57B
58B
80B

FIG. 6C3

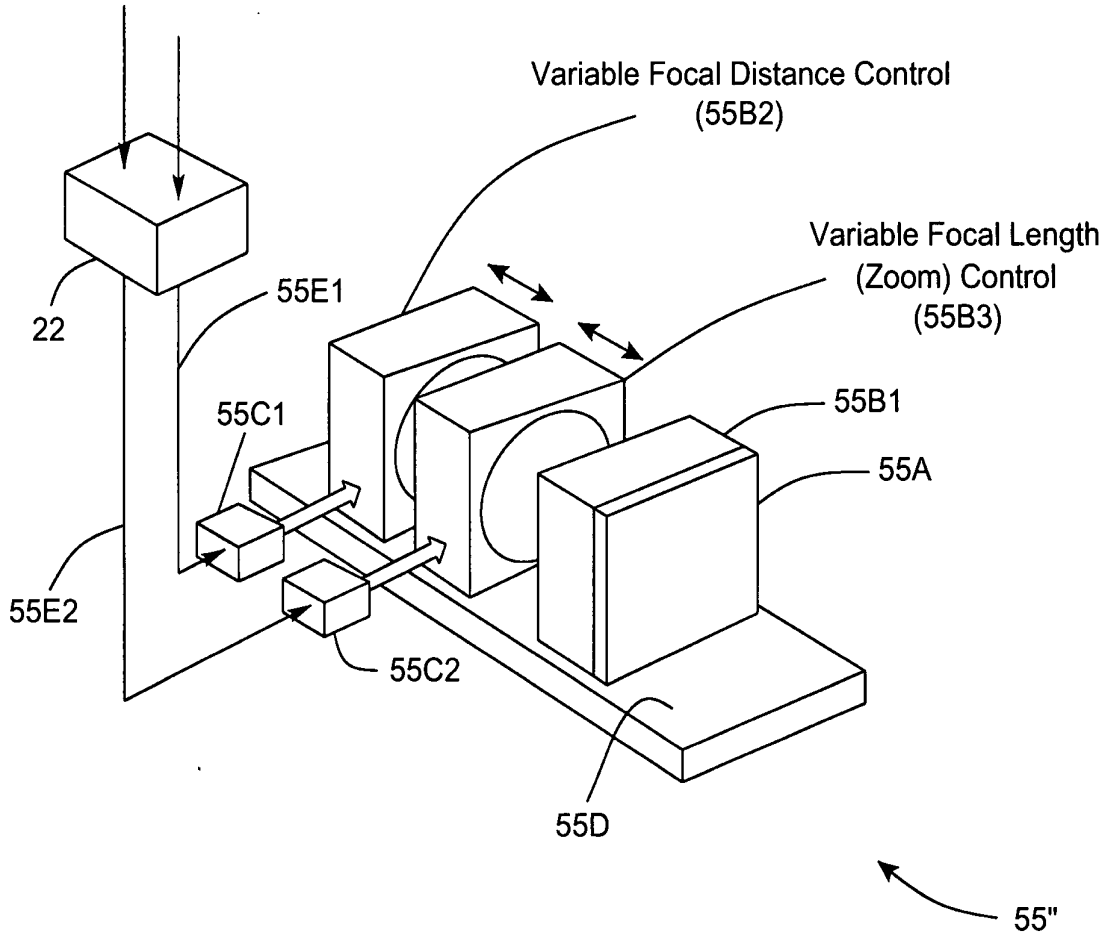

Variable Focal Distance Control
(55B2)
Variable Focal Length
(Zoom) Control
(55B3)
22
55E1
55C1
55B1
55A
55E2
55C2
55D
55"

FIG. 6C4

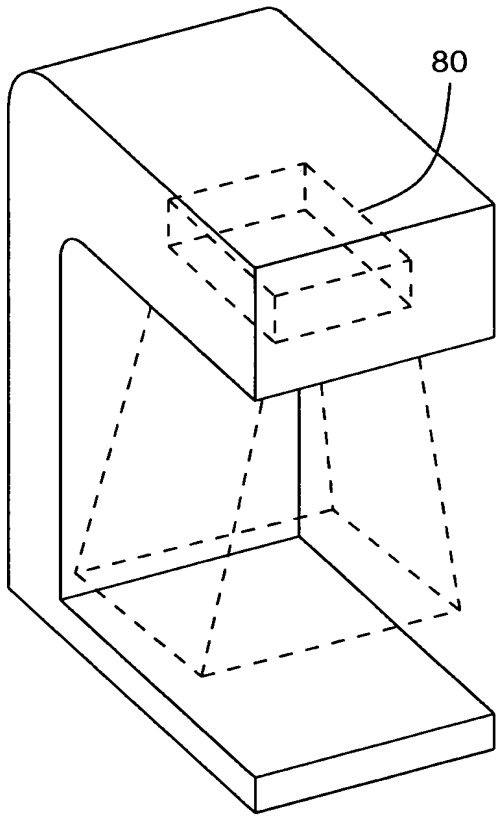


FIG. 6D

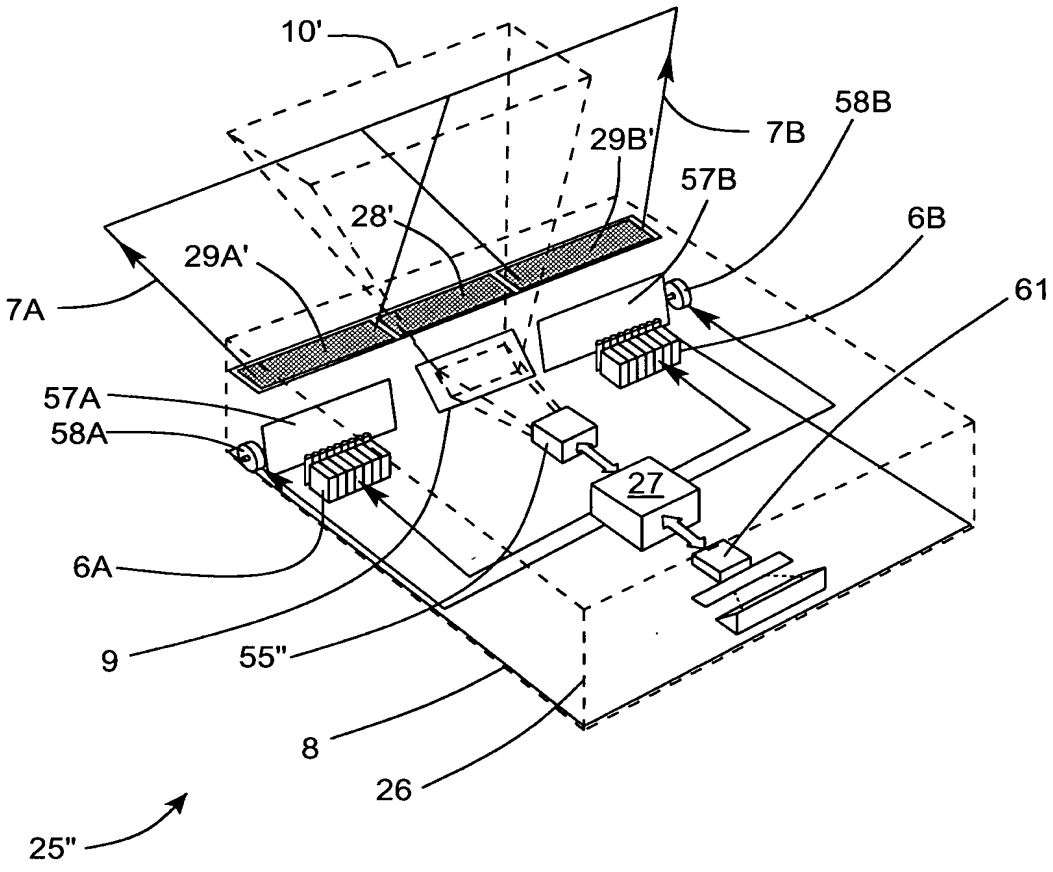


FIG. 6D1

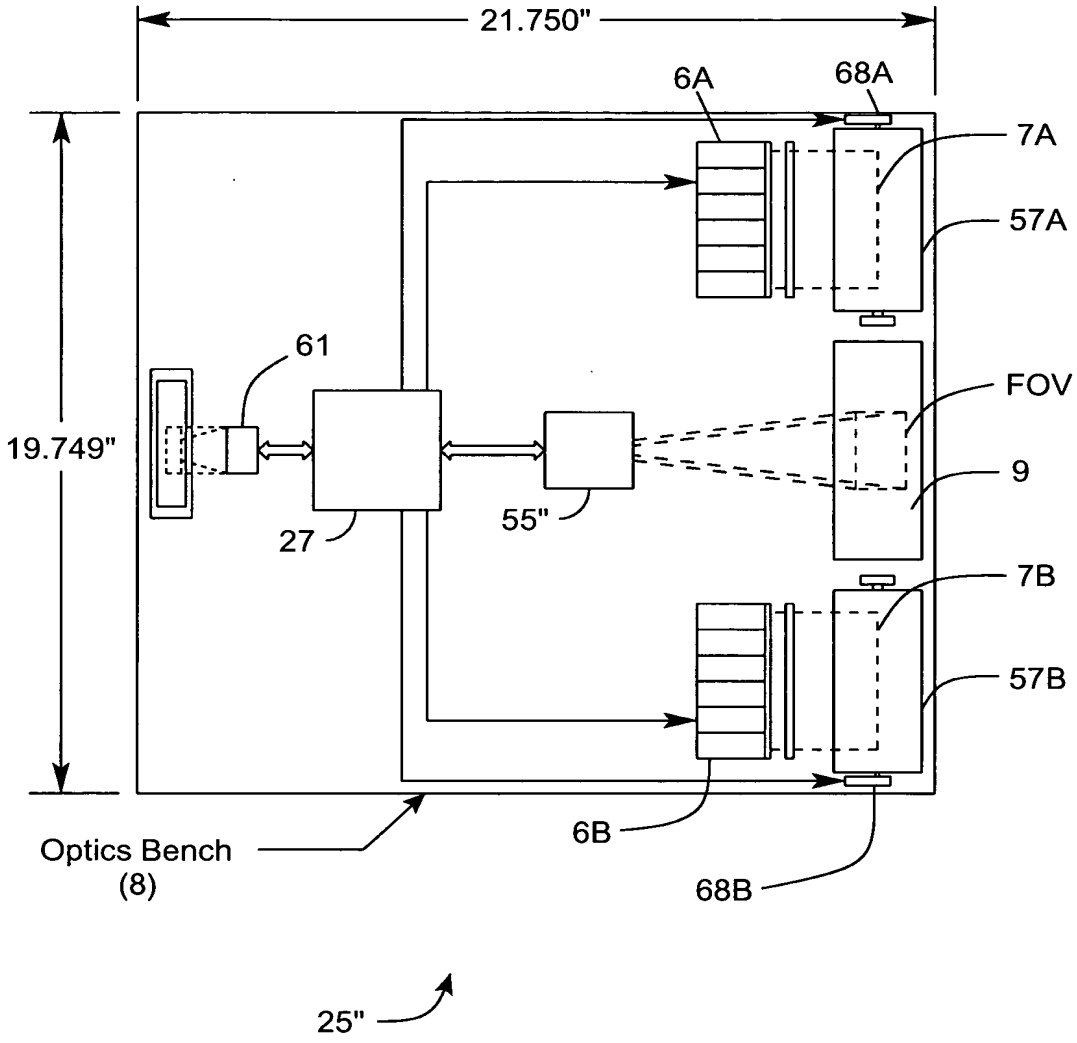

21.750"
6A
68A
7A
57A
61
19.749"
FOV
9
27
55"
7B
57B
Optics Bench
(8)
6B
68B
25"

FIG. 6D2

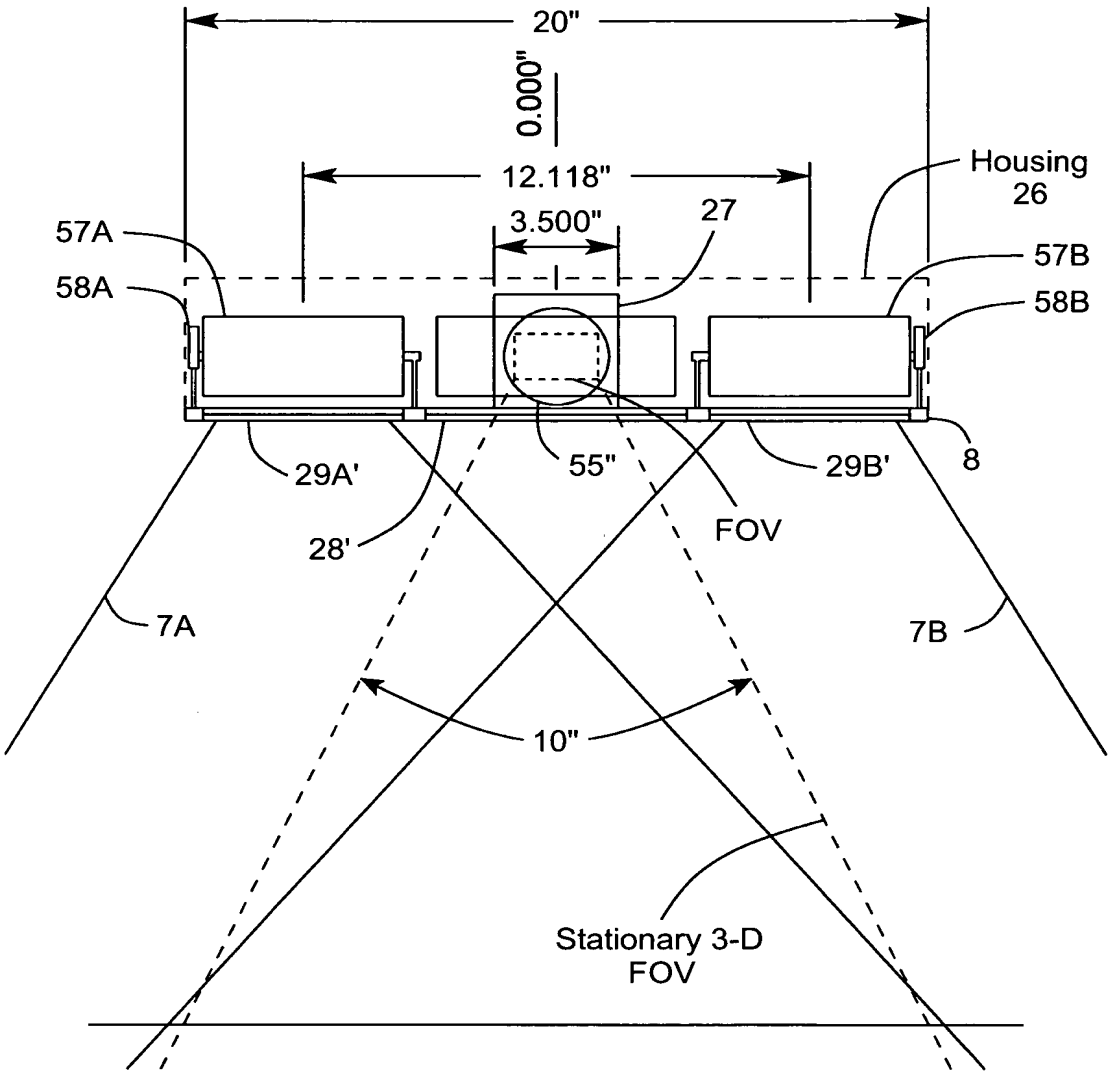

20"
0.000"
12.118"
3.500"
27
Housing
26
57A
58A
57B
58B
29A'
55"
29B'
8
28'
FOV
7A
7B
10"
Stationary 3-D
FOV

FIG. 6D3

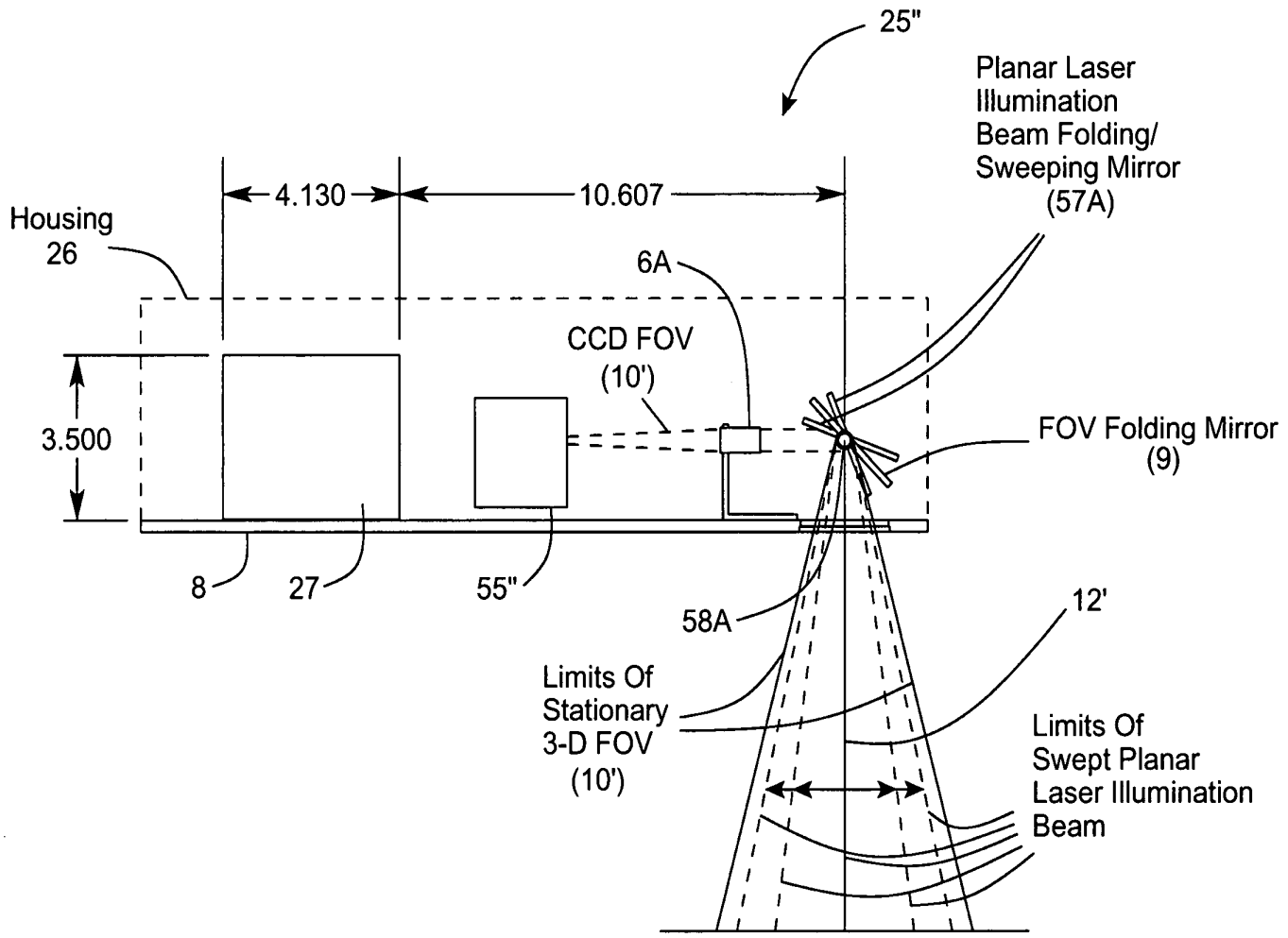

25"
Planar Laser
Illumination
Beam Folding/
Sweeping Mirror
(57A)
4.130
10.607
Housing
26
6A
CCD FOV
(10')
3.500
FOV Folding Mirror
(9)
8
27
55"
58A
12'
Limits Of
Stationary
3-D FOV
(10')
Limits Of
Swept Planar
Laser Illumination
Beam

FIG. 6D4

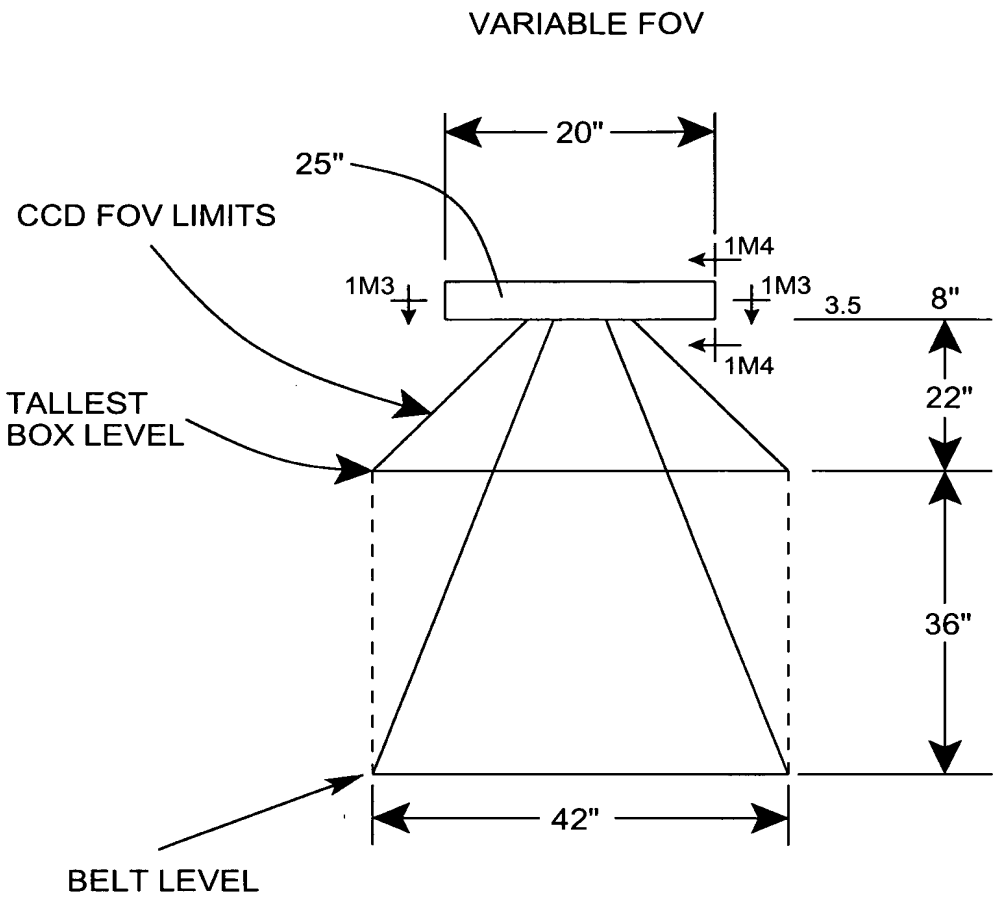

VARIABLE FOV
20"
25"
CCD FOV LIMITS
1M4
1M3
1M3
3.5
8"
1M4
22"
TALLEST
BOX LEVEL
36"
42"
BELT LEVEL

FIG. 6D5

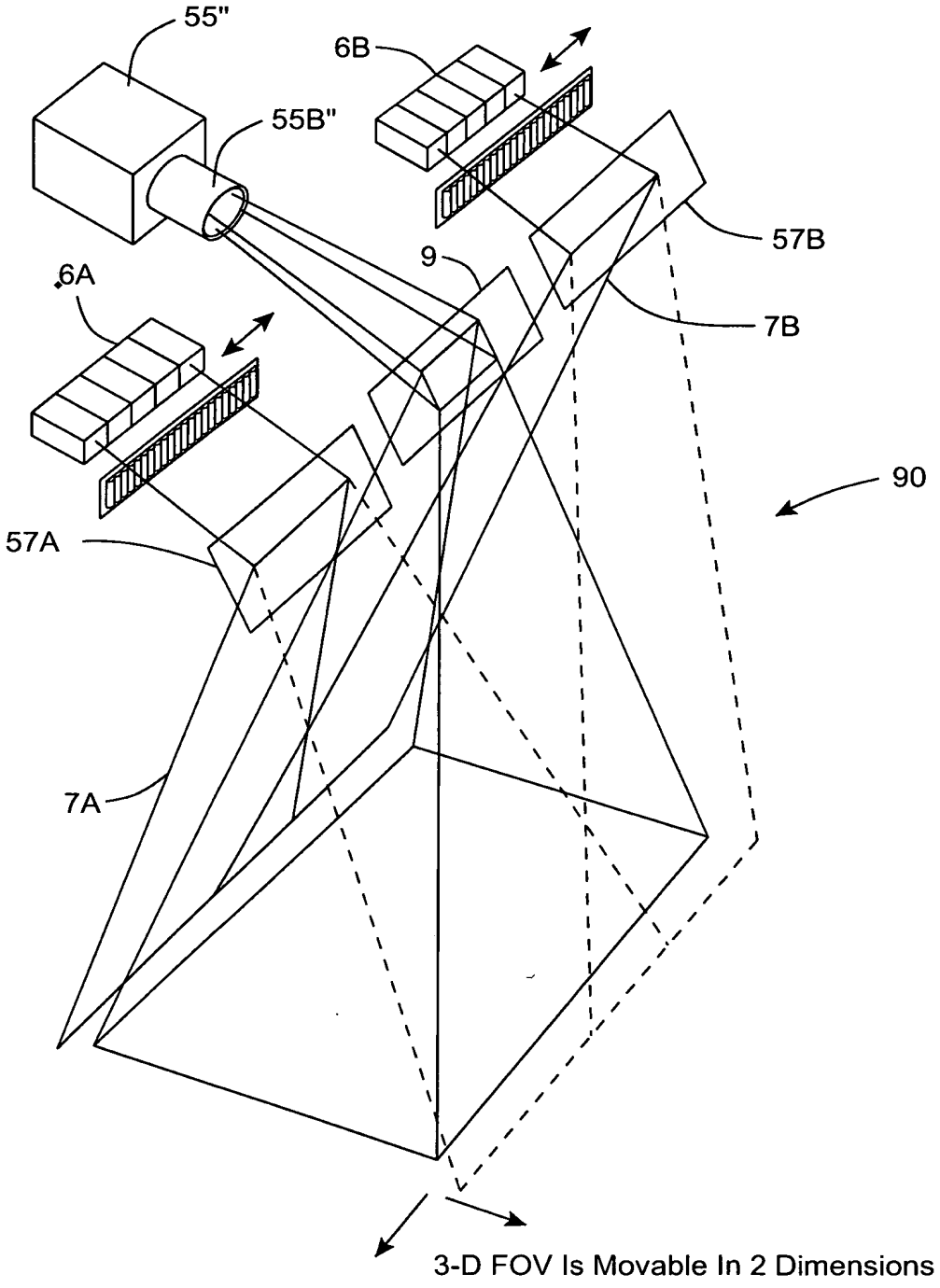


FIG. 6E1

(1) Variable Focal Length Camera Lens
(2) Variable Focal Distance

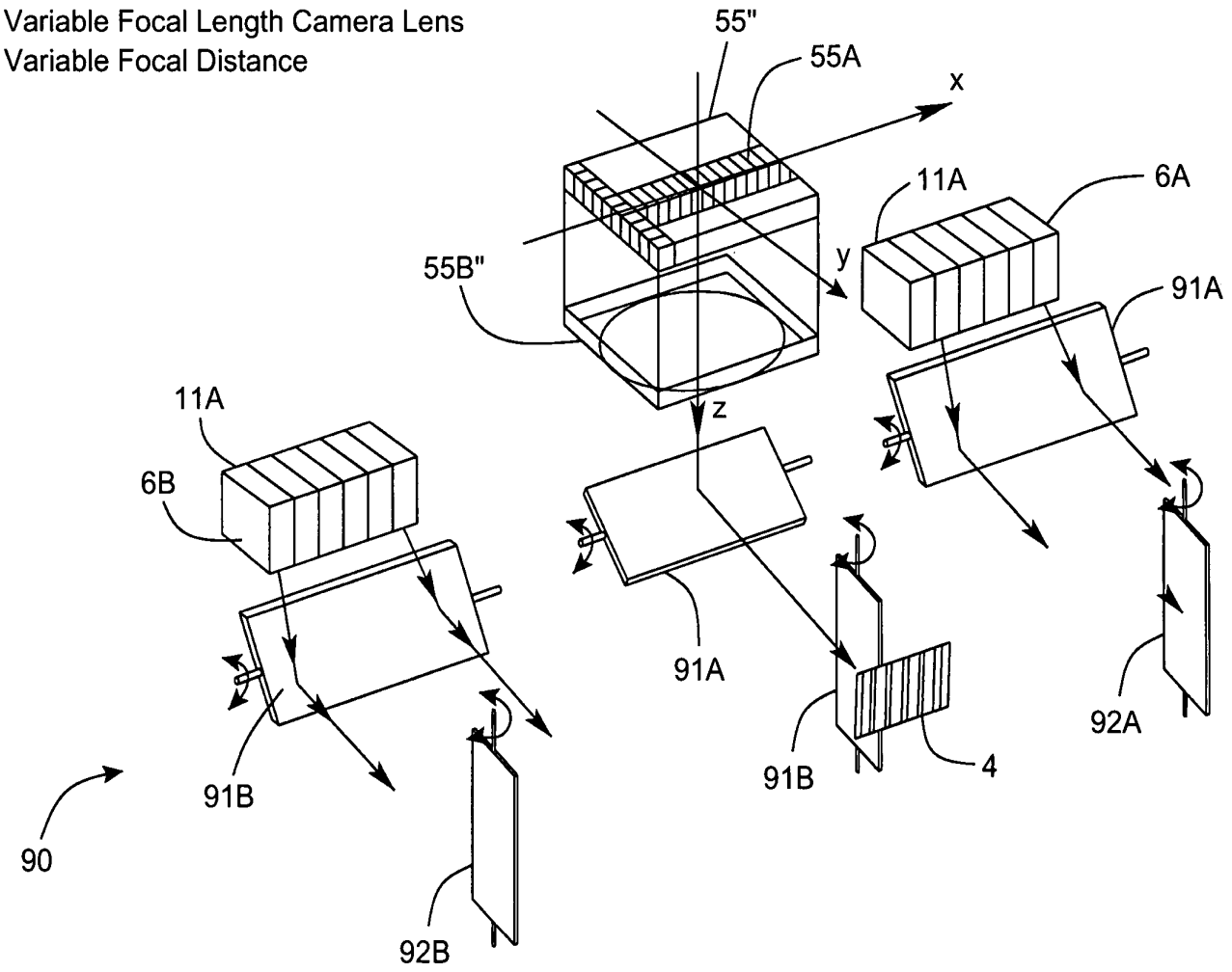


FIG. 6E2

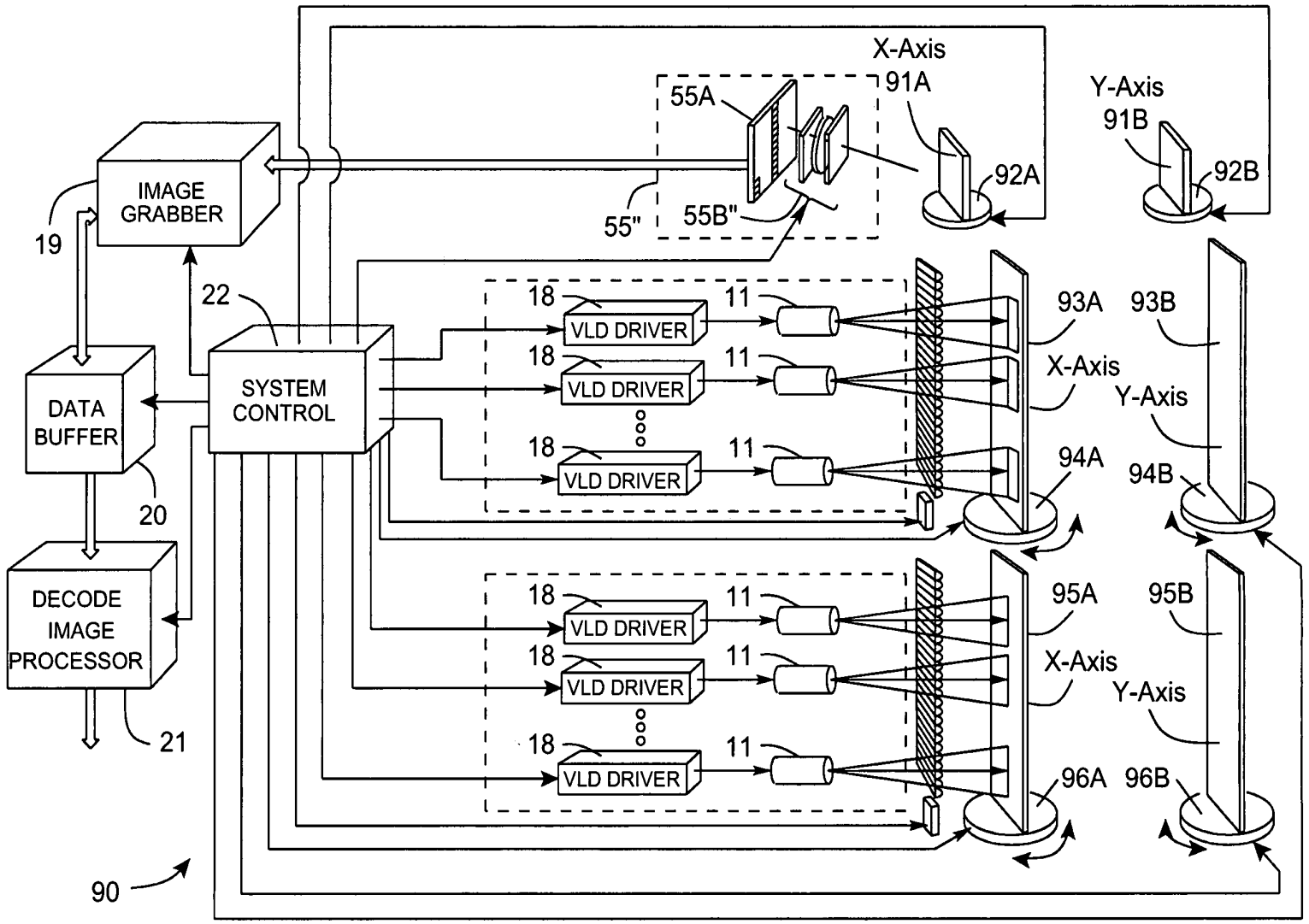


IMAGE GRABBER
19
22
SYSTEM CONTROL
DATA BUFFER
20
DECODE IMAGE PROCESSOR
21
90
55A
55"
55B"
X-Axis
91A
92A
Y-Axis
91B
92B
18
VLD DRIVER
11
93A
93B
X-Axis
Y-Axis
94A
94B
95A
95B
96A
96B

FIG. 6E3

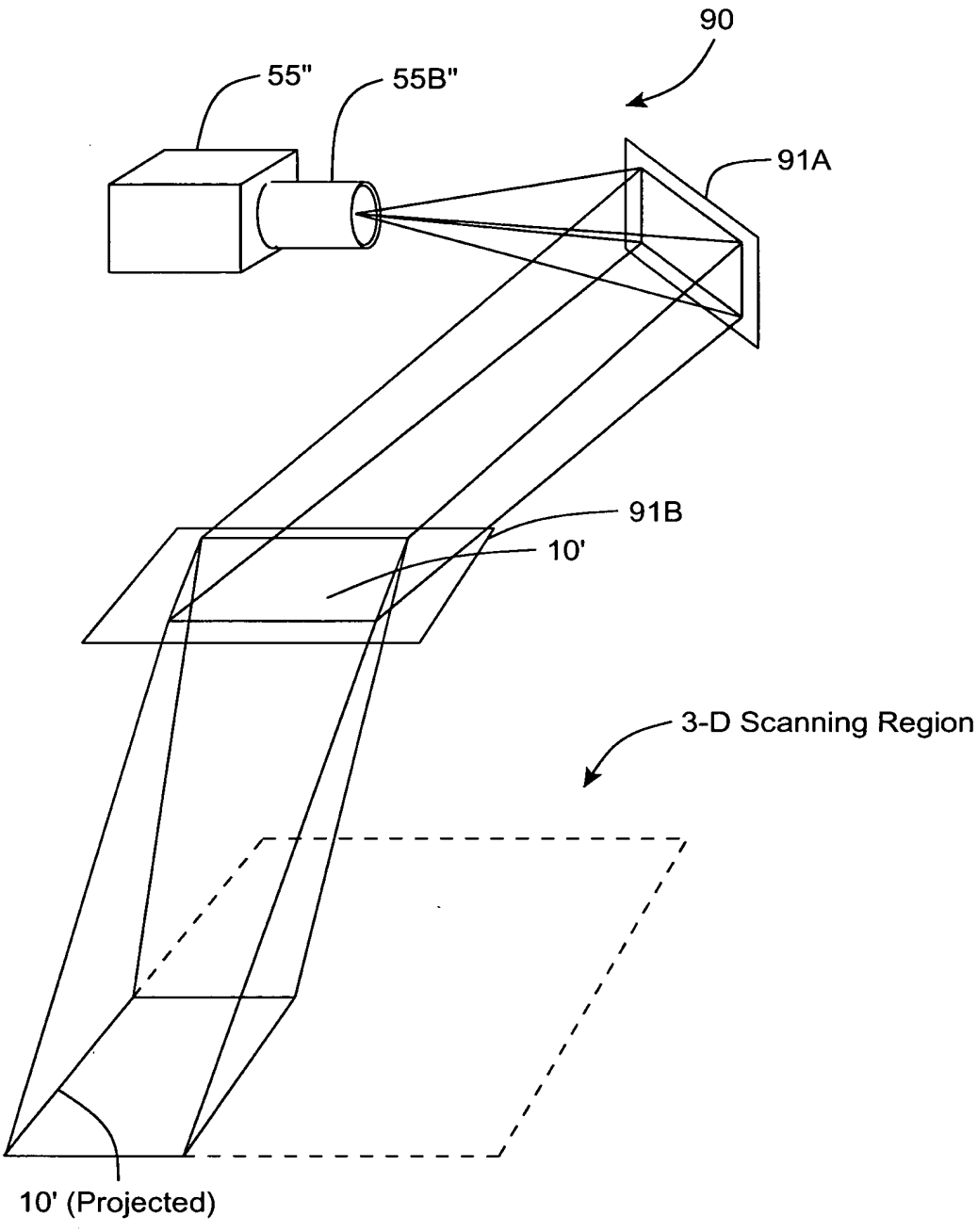


FIG. 6E4

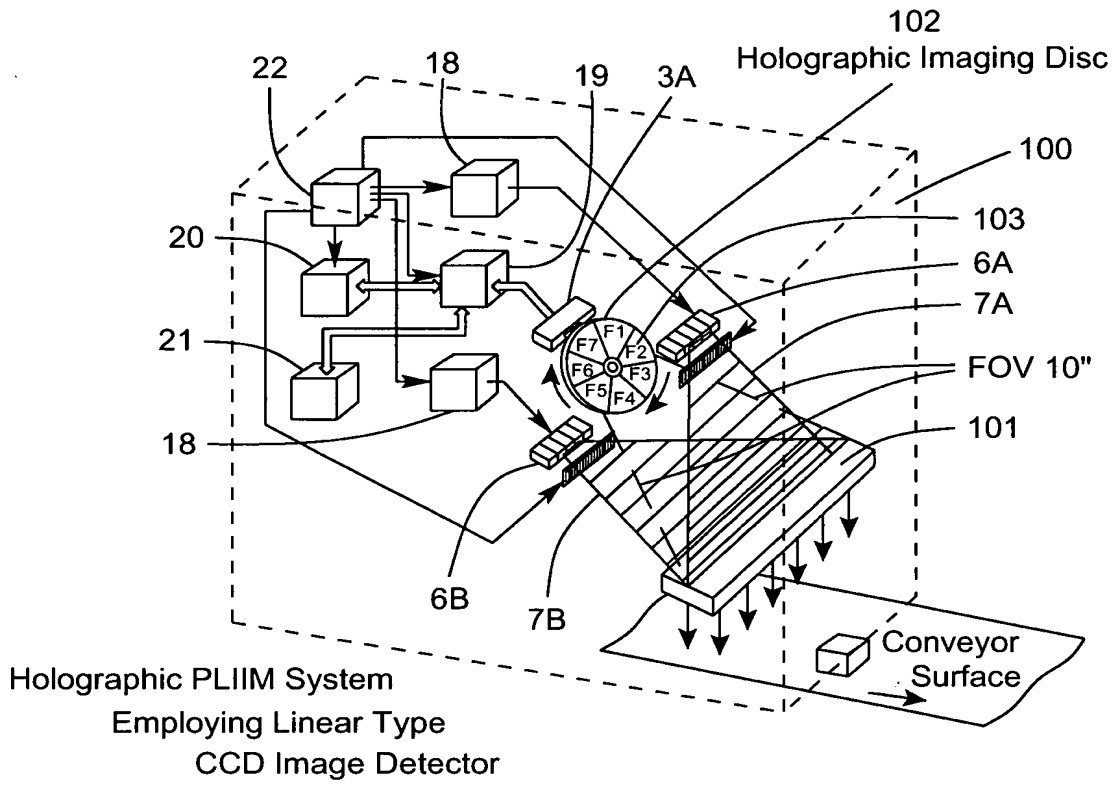

102
Holographic Imaging Disc
22
18
19
3A
100
103
20
6A
7A
21
F1
F2
F3
F4
F5
F6
F7
FOV 10"
18
101
6B
7B
Conveyor
Surface
Holographic PLIIM System
Employing Linear Type
CCD Image Detector

FIG. 7A

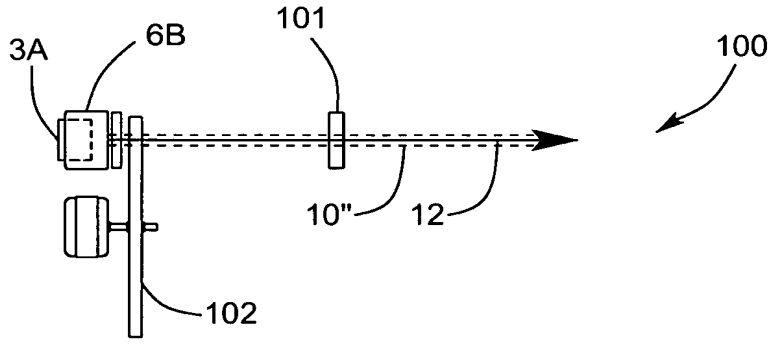

3A
6B
101
100
10"
12
102

FIG. 7B

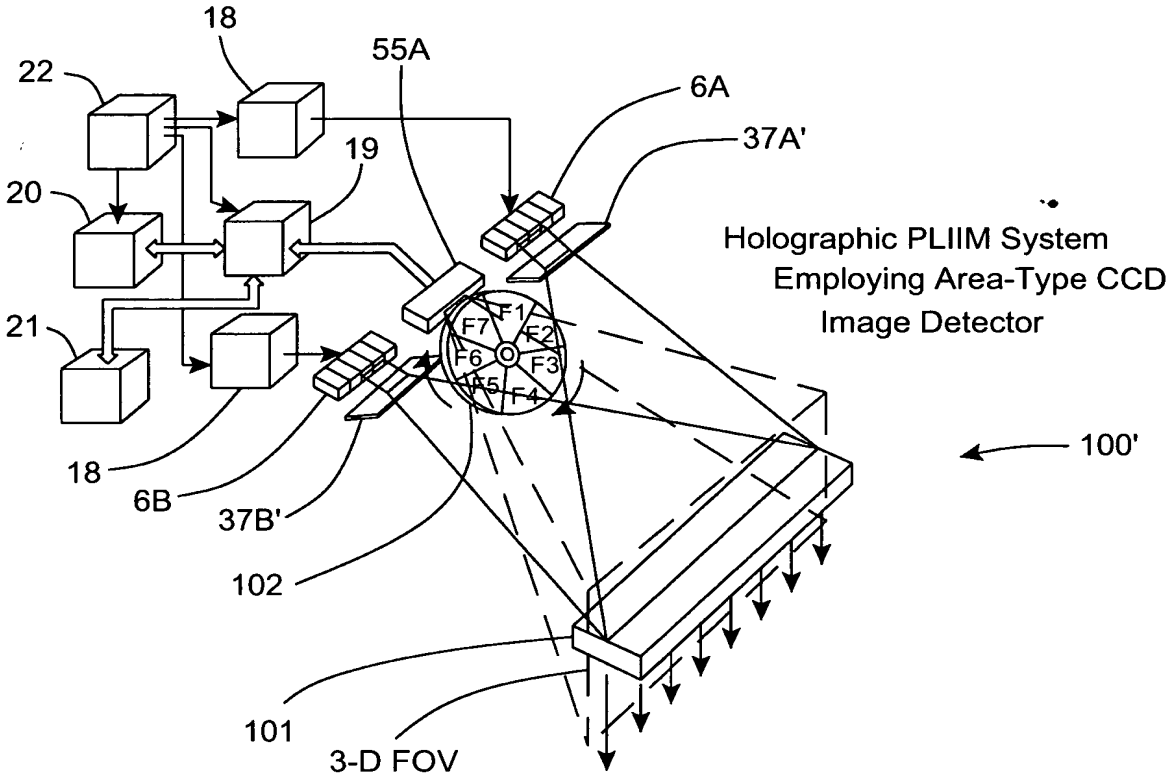

18
55A
22
6A
37A'
19
20
Holographic PLIIM System
Employing Area-Type CCD
Image Detector
21
F7
F1
F2
F6
F3
F5
F4
100'
18
6B
37B'
102
101
3-D FOV

FIG. 8A

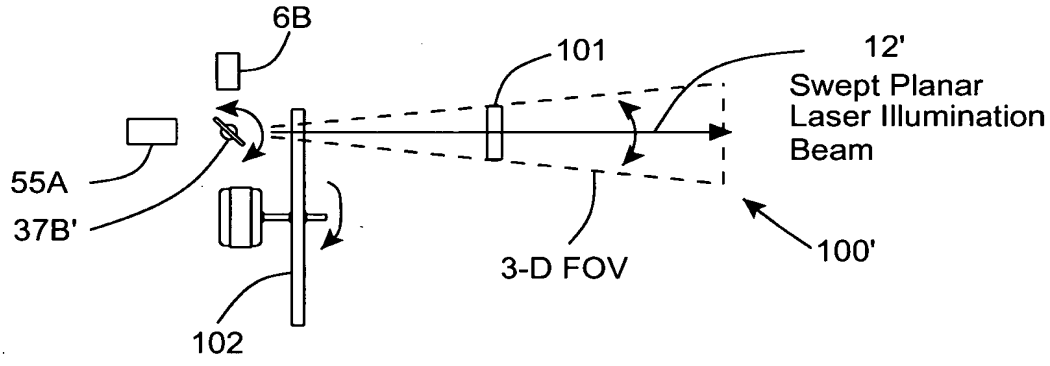

6B
101
12'
Swept Planar
Laser Illumination
Beam
55A
37B'
3-D FOV
100'
102

FIG. 8B

1-D CCD Scanner Embodiment

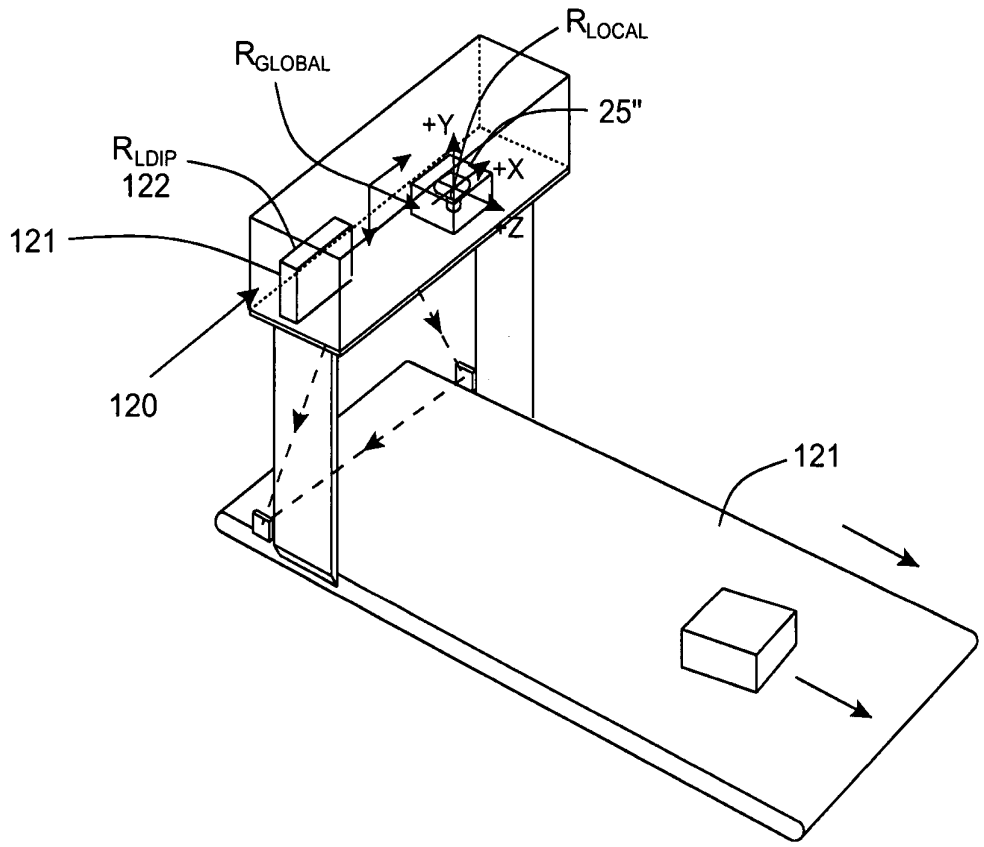


FIG. 9

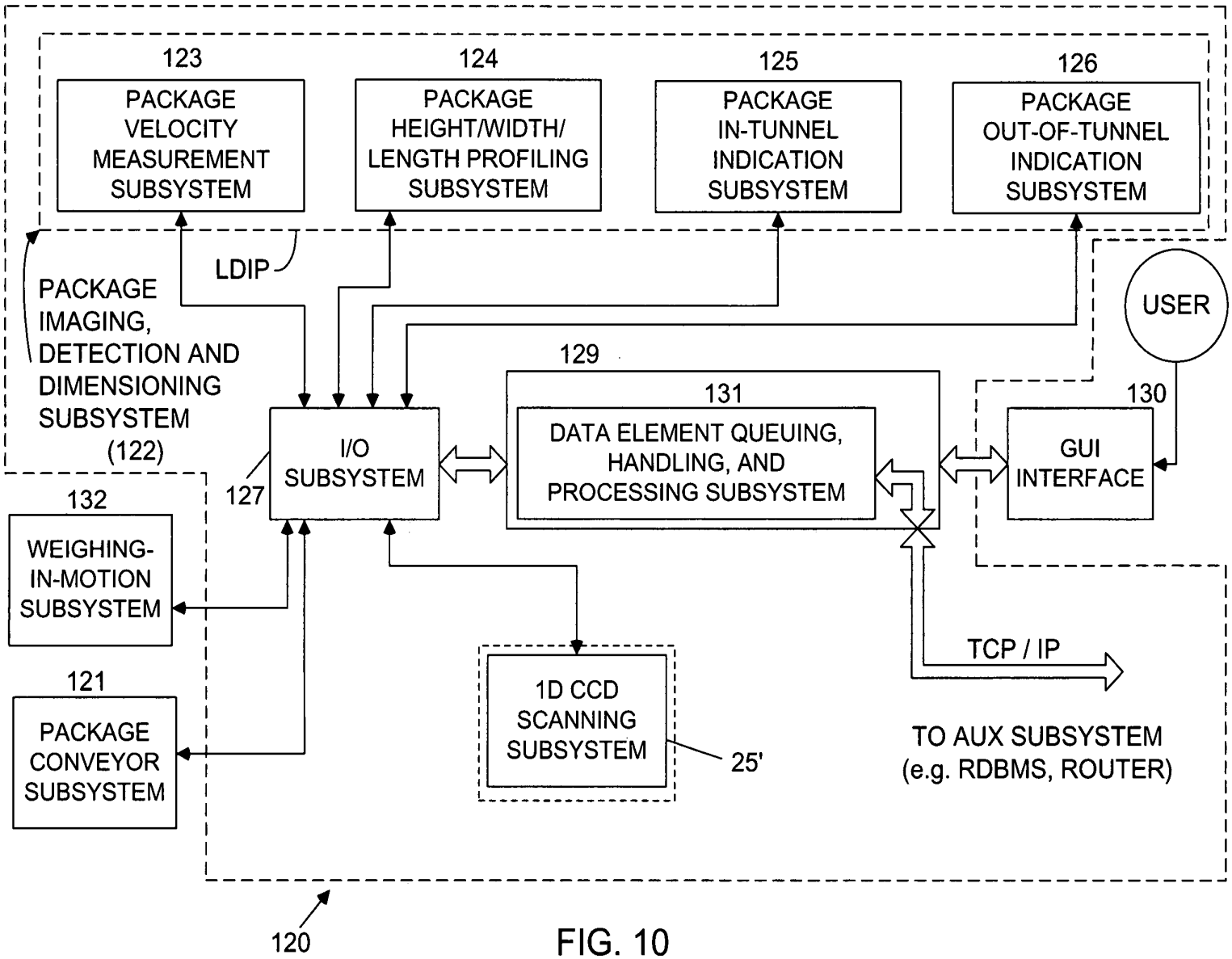

123
PACKAGE VELOCITY MEASUREMENT SUBSYSTEM
124
PACKAGE HEIGHT/WIDTH/ LENGTH PROFILING SUBSYSTEM
125
PACKAGE IN-TUNNEL INDICATION SUBSYSTEM
126
PACKAGE OUT-OF-TUNNEL INDICATION SUBSYSTEM
LDIP
PACKAGE IMAGING, DETECTION AND DIMENSIONING SUBSYSTEM (122)
USER
129
131
130
I/O SUBSYSTEM
127
DATA ELEMENT QUEUING, HANDLING, AND PROCESSING SUBSYSTEM
GUI INTERFACE
132
WEIGHING-IN-MOTION SUBSYSTEM
121
PACKAGE CONVEYOR SUBSYSTEM
1D CCD SCANNING SUBSYSTEM
25'
TCP / IP
TO AUX SUBSYSTEM (e.g. RDBMS, ROUTER)
120

FIG. 10

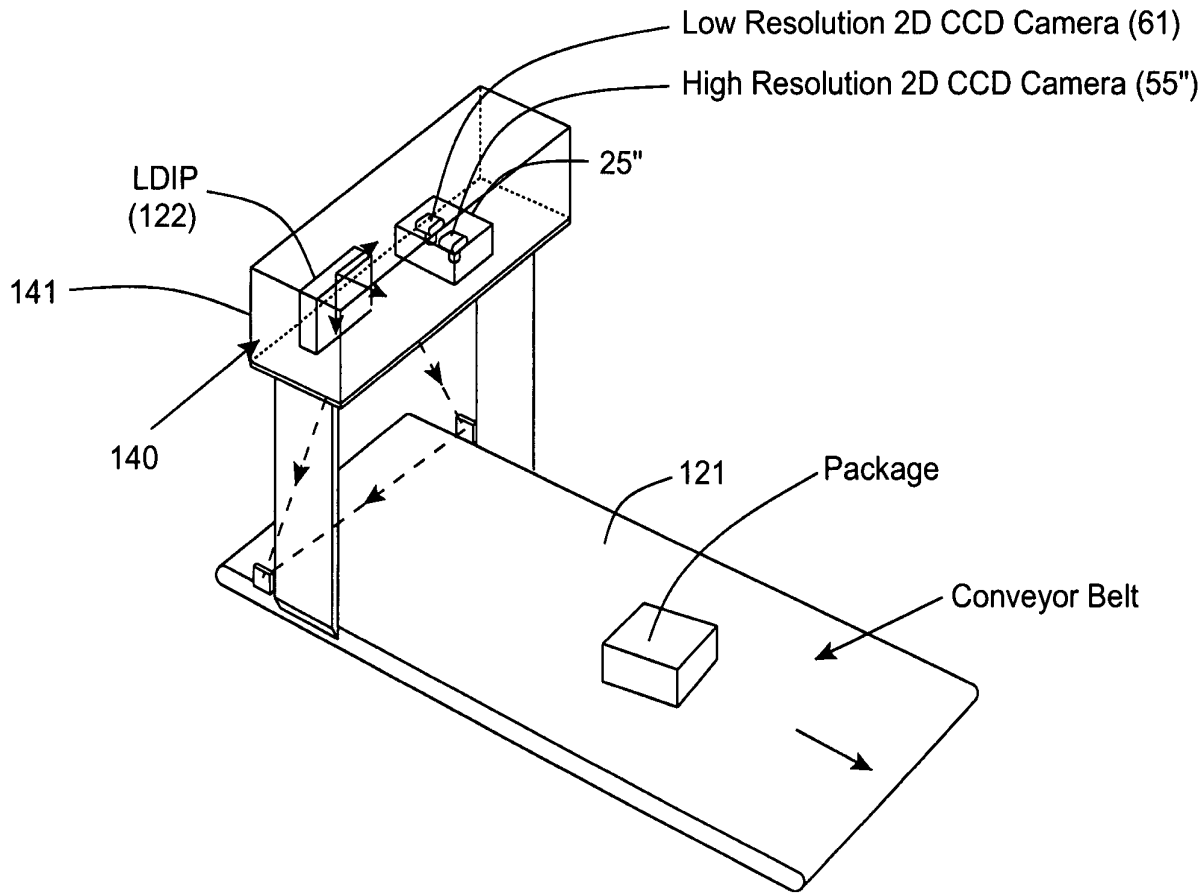

Low Resolution 2D CCD Camera (61)
High Resolution 2D CCD Camera (55")
25"
LDIP
(122)
141
140
121
Package
Conveyor Belt

FIG. 11

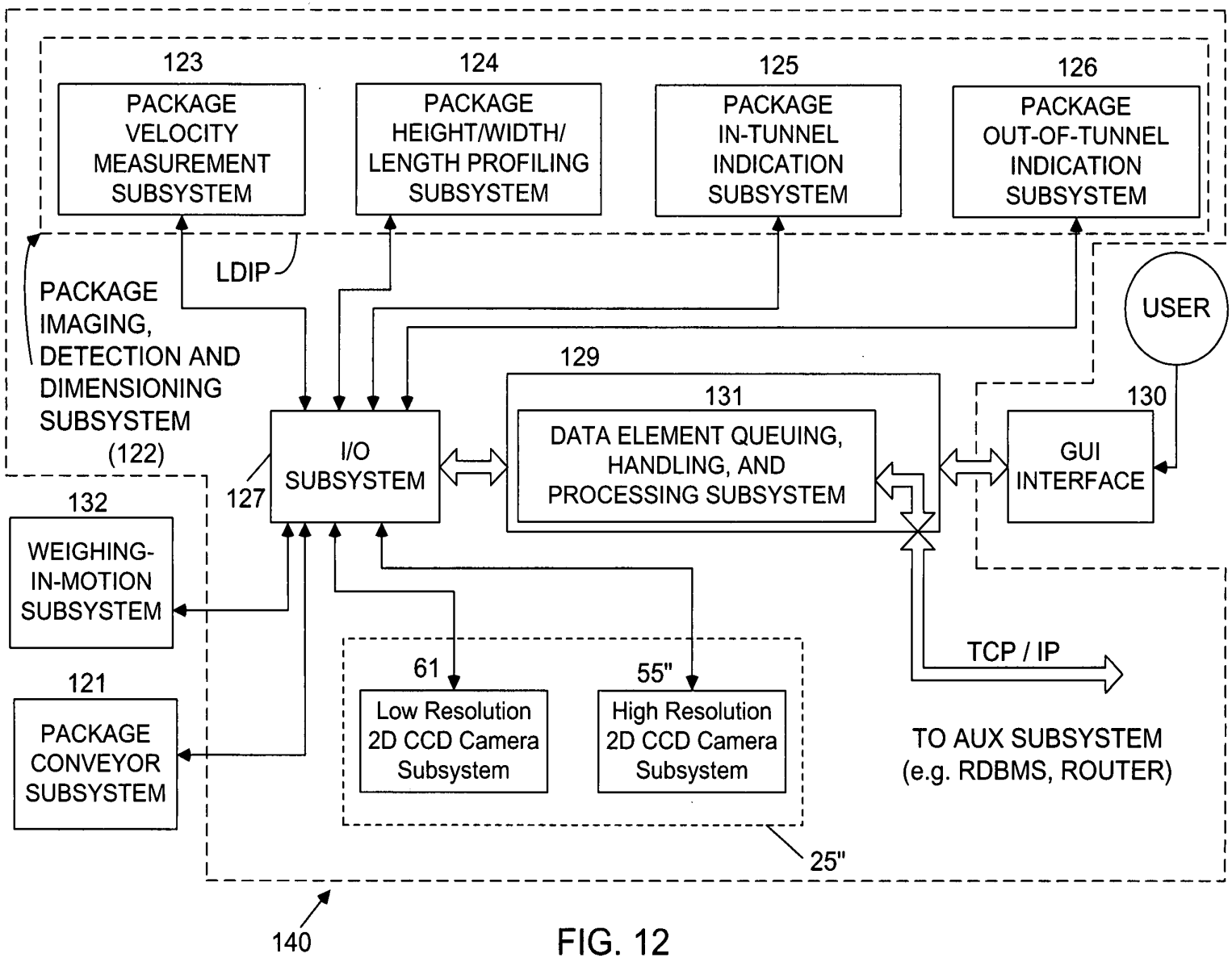

123
PACKAGE VELOCITY MEASUREMENT SUBSYSTEM
124
PACKAGE HEIGHT/WIDTH/ LENGTH PROFILING SUBSYSTEM
125
PACKAGE IN-TUNNEL INDICATION SUBSYSTEM
126
PACKAGE OUT-OF-TUNNEL INDICATION SUBSYSTEM
LDIP
PACKAGE IMAGING, DETECTION AND DIMENSIONING SUBSYSTEM (122)
USER
129
131
130
127
I/O SUBSYSTEM
DATA ELEMENT QUEUING, HANDLING, AND PROCESSING SUBSYSTEM
GUI INTERFACE
132
WEIGHING-IN-MOTION SUBSYSTEM
121
PACKAGE CONVEYOR SUBSYSTEM
61
Low Resolution 2D CCD Camera Subsystem
55"
High Resolution 2D CCD Camera Subsystem
TCP / IP
TO AUX SUBSYSTEM (e.g. RDBMS, ROUTER)
25"
140

FIG. 12

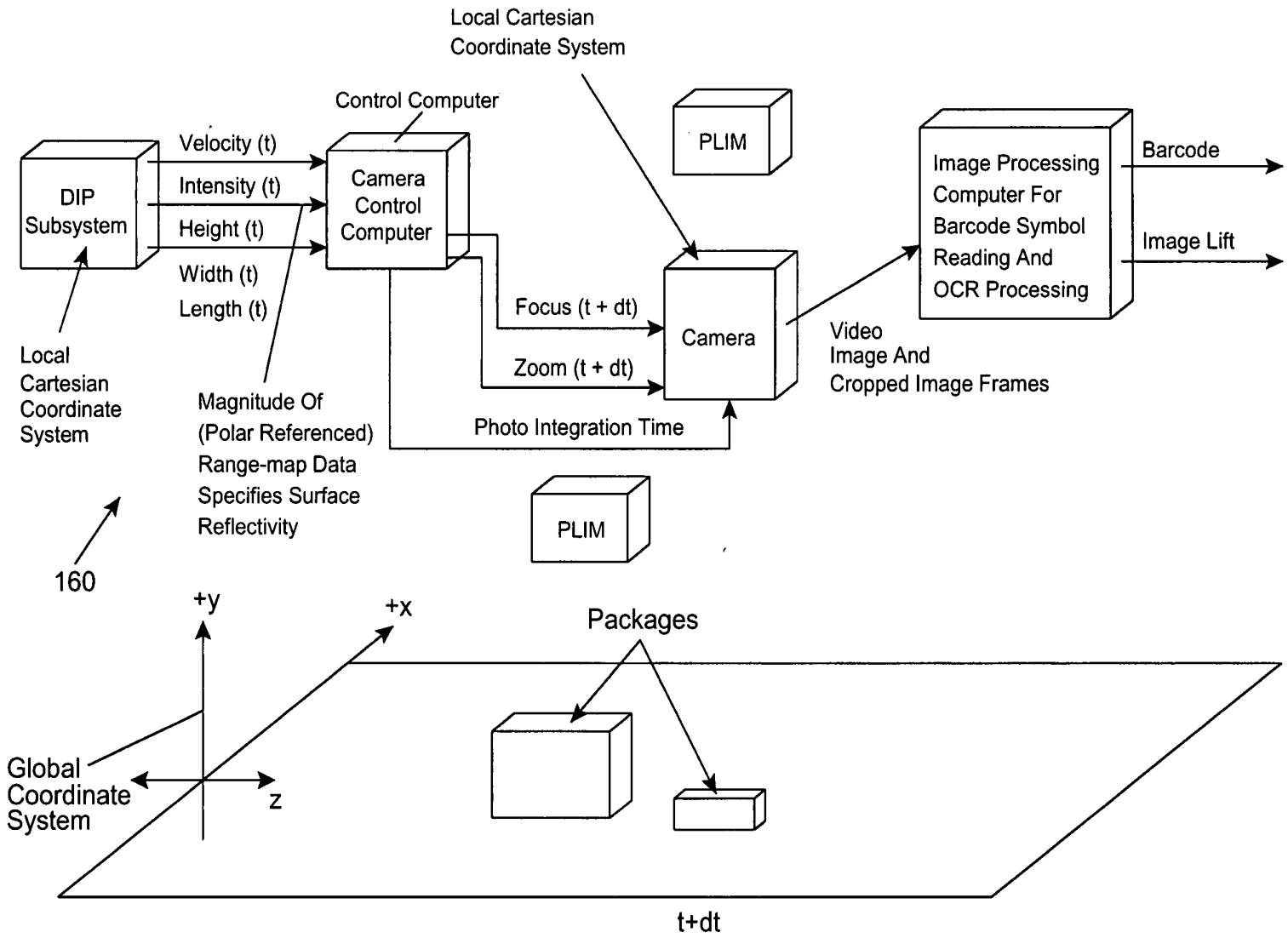

Local Cartesian
Coordinate System
Control Computer
PLIM
Image Processing
Computer For
Barcode Symbol
Reading And
OCR Processing
Barcode
Image Lift
DIP
Subsystem
Velocity (t)
Intensity (t)
Height (t)
Width (t)
Length (t)
Camera
Control
Computer
Focus (t + dt)
Zoom (t + dt)
Camera
Video
Image And
Cropped Image Frames
Local
Cartesian
Coordinate
System
Magnitude Of
(Polar Referenced)
Range-map Data
Specifies Surface
Reflectivity
Photo Integration Time
PLIM
160
+y
+x
Packages
Global
Coordinate
System
z
t+dt

FIG. 13

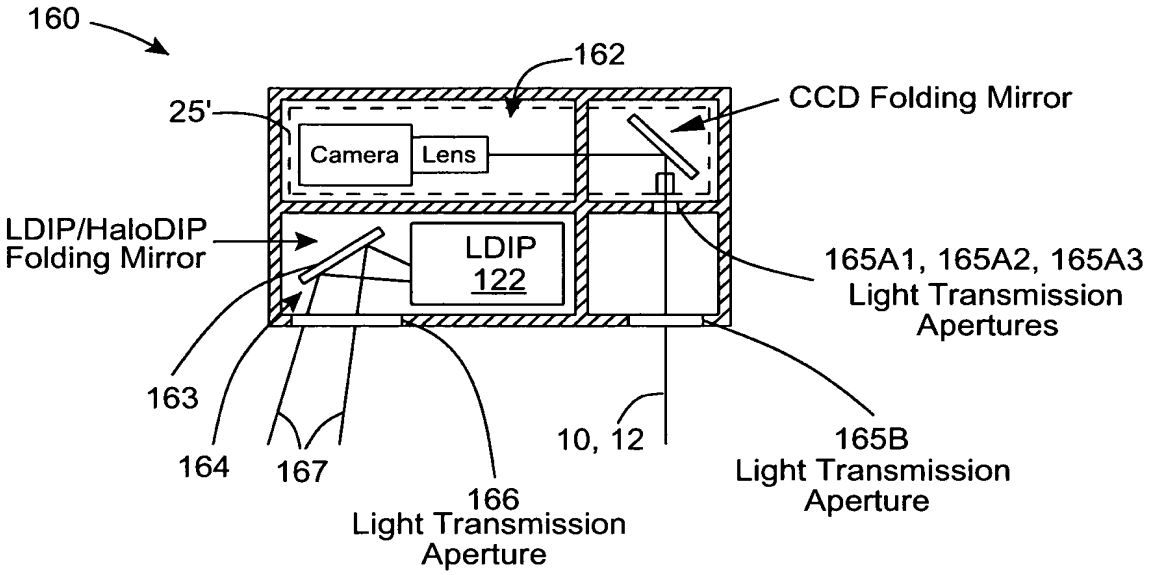


FIG. 14A

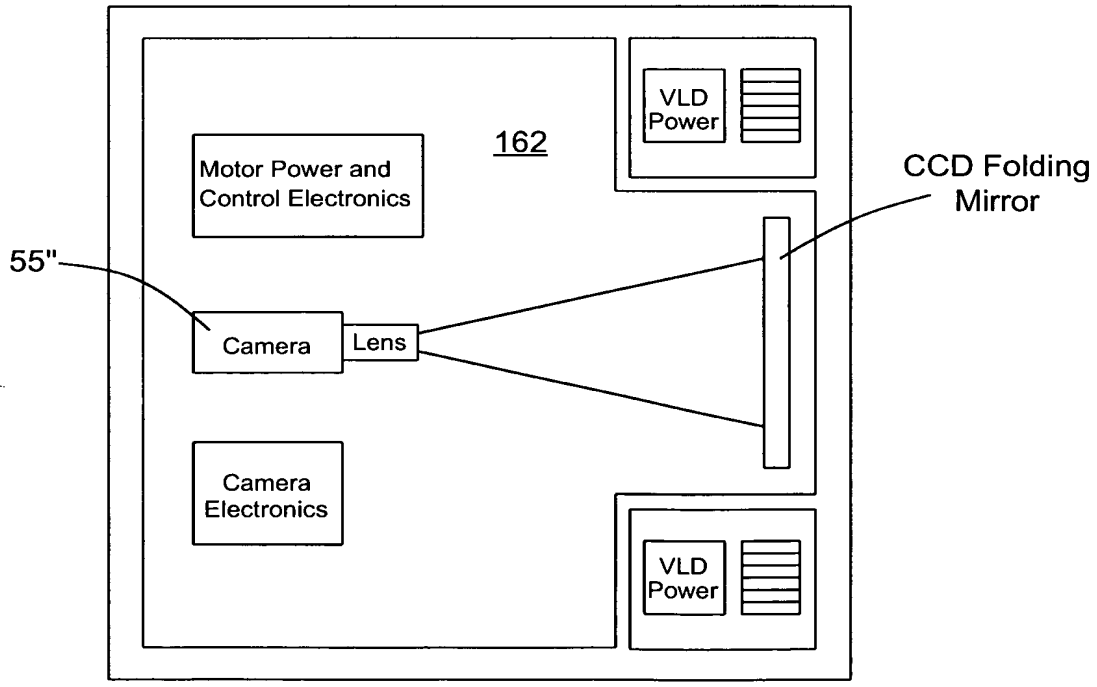


FIG. 14B

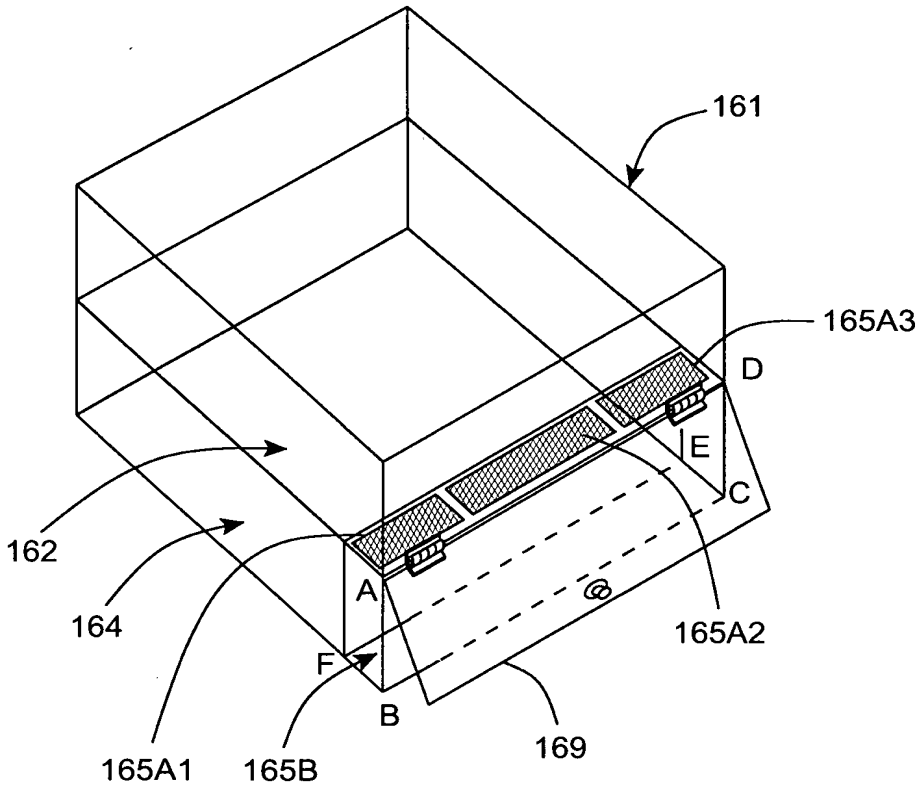


FIG. 15

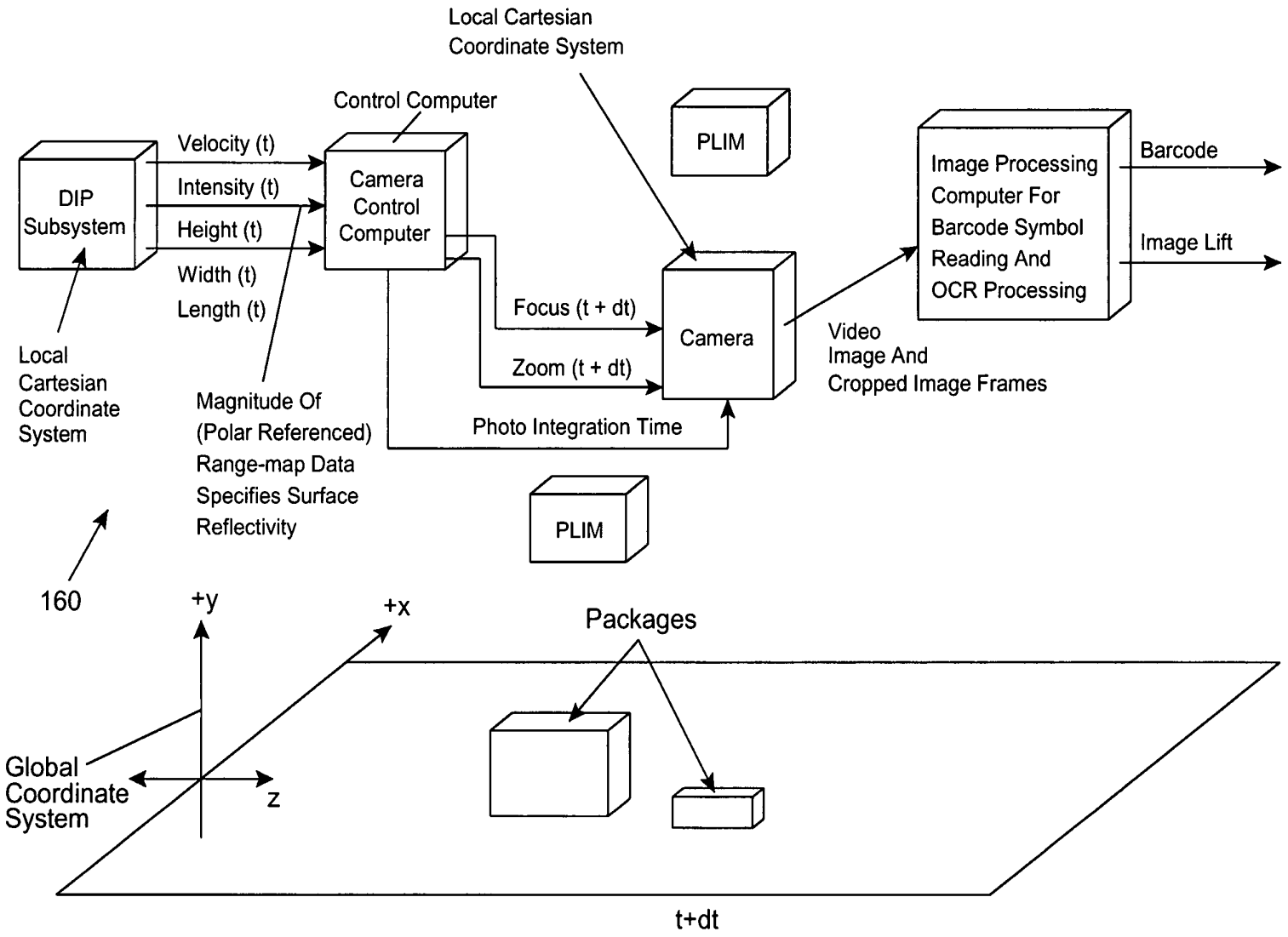

Local Cartesian
Coordinate System
Control Computer
PLIM
Image Processing
Computer For
Barcode Symbol
Reading And
OCR Processing
Barcode
Image Lift
DIP
Subsystem
Velocity (t)
Intensity (t)
Height (t)
Width (t)
Length (t)
Camera
Control
Computer
Focus (t + dt)
Zoom (t + dt)
Camera
Video
Image And
Cropped Image Frames
Local
Cartesian
Coordinate
System
Magnitude Of
(Polar Referenced)
Range-map Data
Specifies Surface
Reflectivity
Photo Integration Time
PLIM
160
+y
+x
Packages
Global
Coordinate
System
z
t+dt

FIG. 16

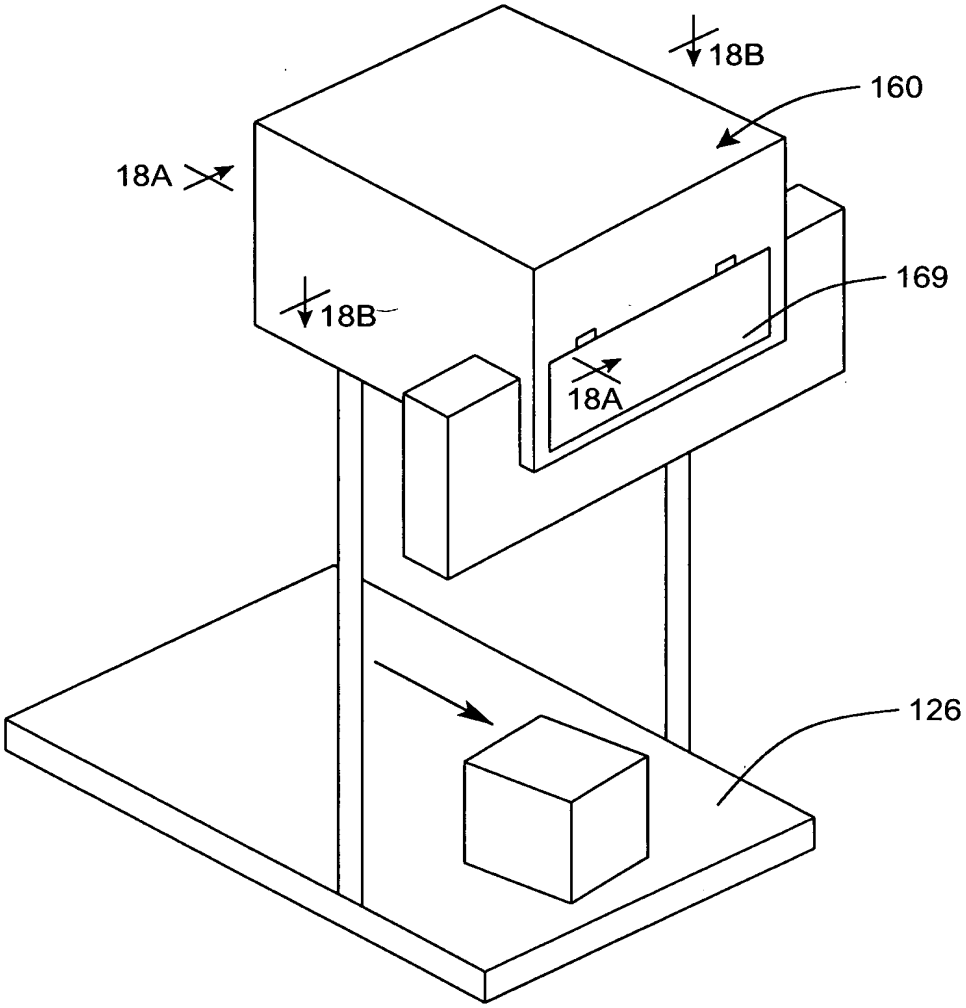


FIG. 17

Upper Deck
Top View

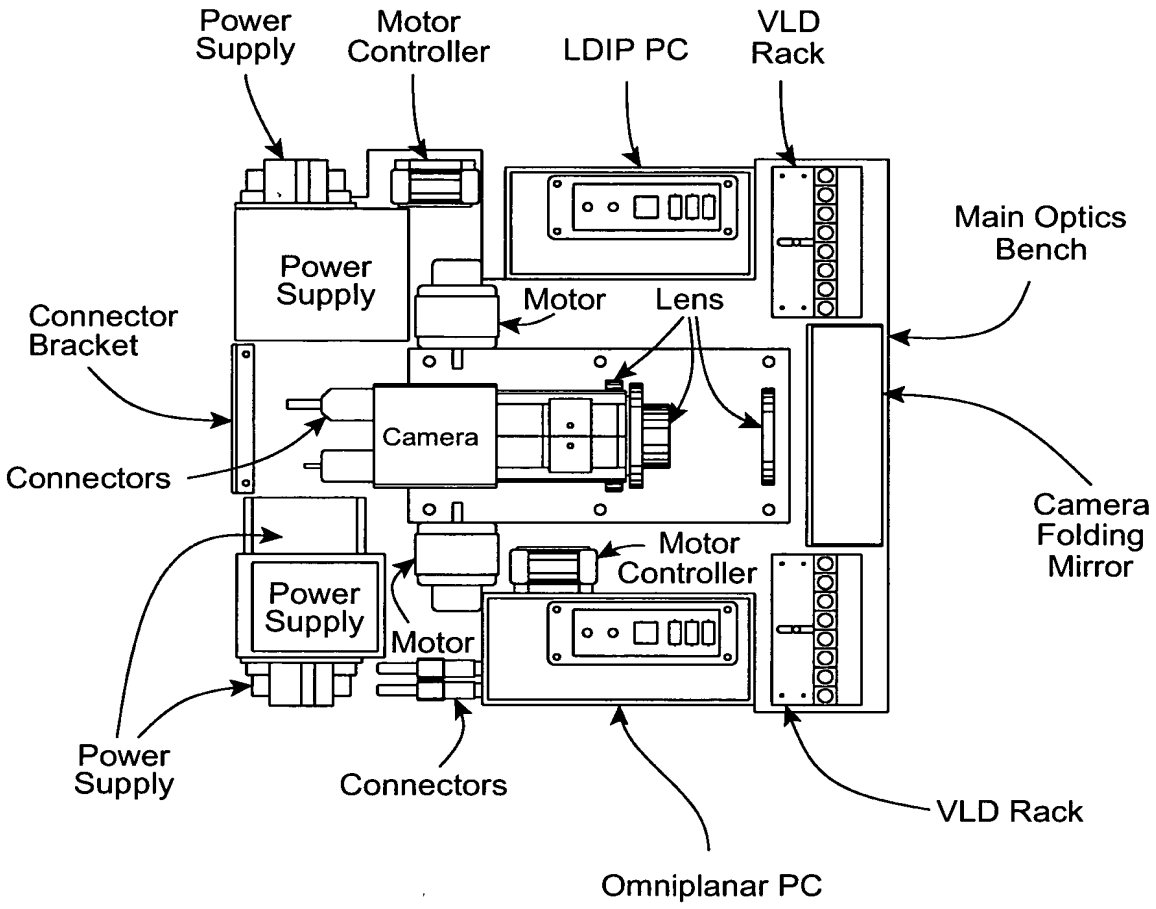


FIG. 18A

Lower Deck
Top View

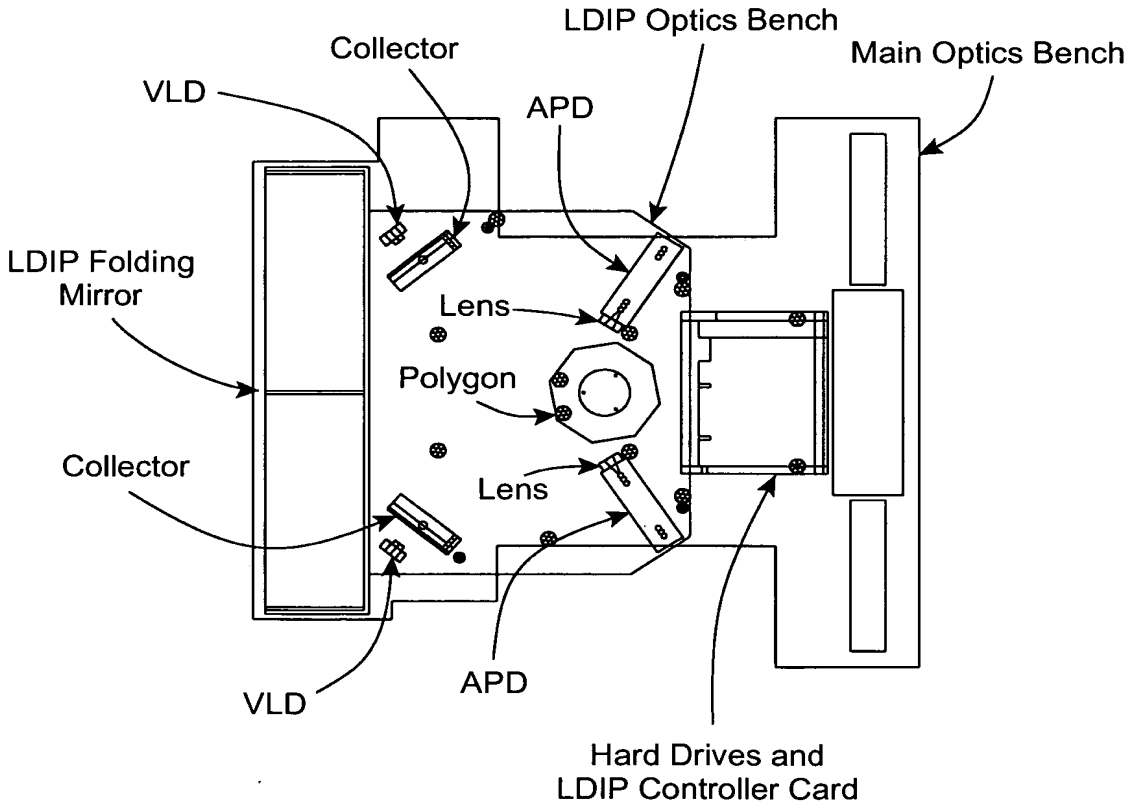
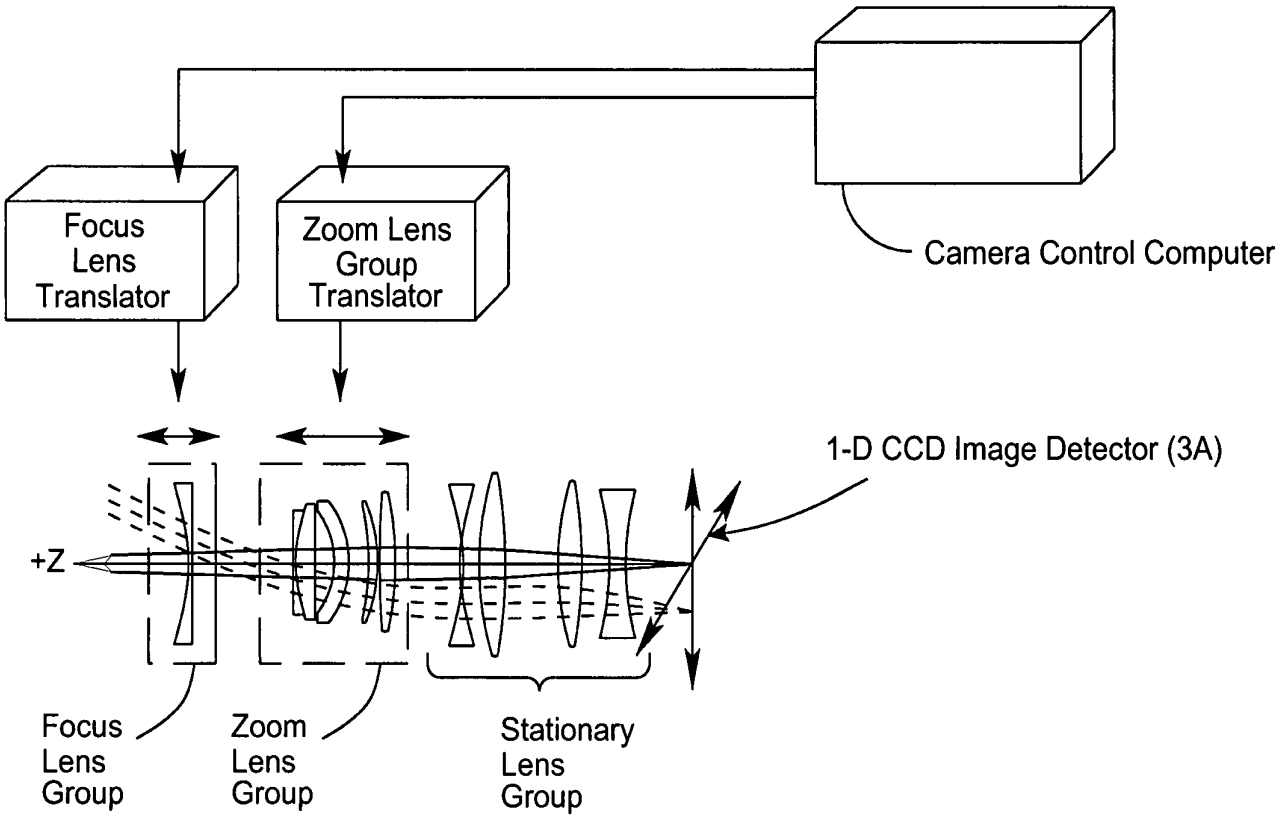


FIG. 18B



Main Optics Lens Groups

FIG. 18C

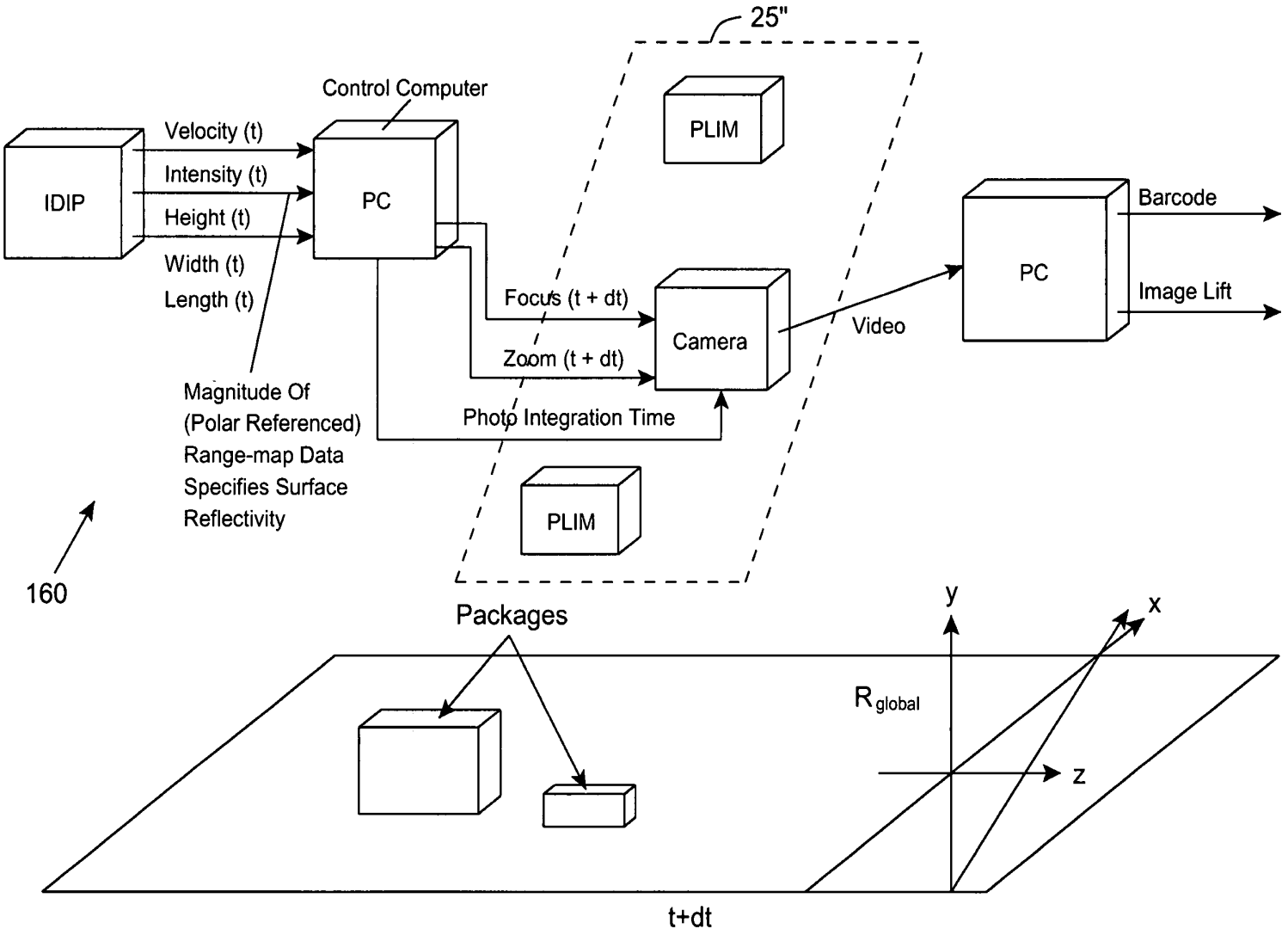

25"
Control Computer
PLIM
IDIP
Velocity (t)
Intensity (t)
Height (t)
Width (t)
Length (t)
PC
Barcode
Image Lift
PC
Focus (t + dt)
Zoom (t + dt)
Camera
Video
Magnitude Of
(Polar Referenced)
Range-map Data
Specifies Surface
Reflectivity
Photo Integration Time
PLIM
160
Packages
y
x
R_{global}
z
t+dt

FIG. 19

PLIIM-BASED PACKAGE IDENTIFICATION AND DIMENSIONING (PID) SYSTEM

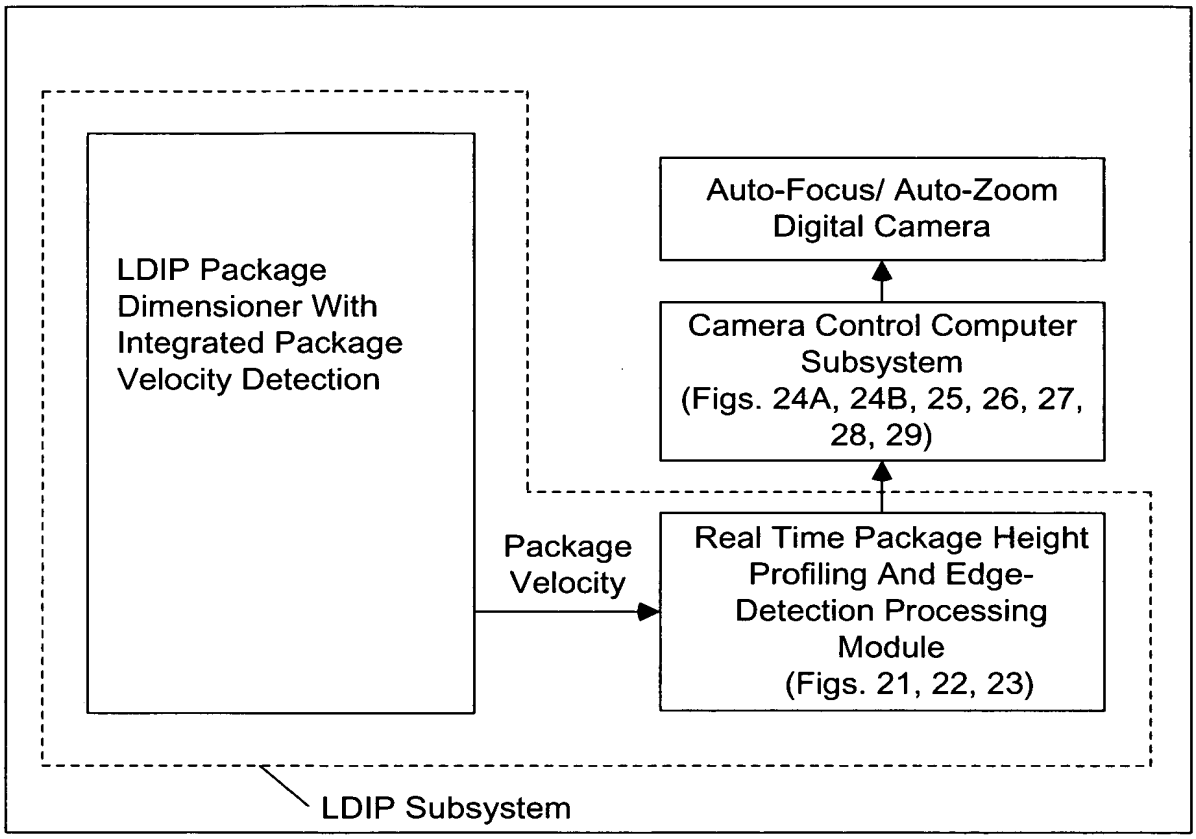


FIG. 20

LDIP REAL-TIME PACKAGE HEIGHT PROFILE AND EDGE DETECTION METHOD

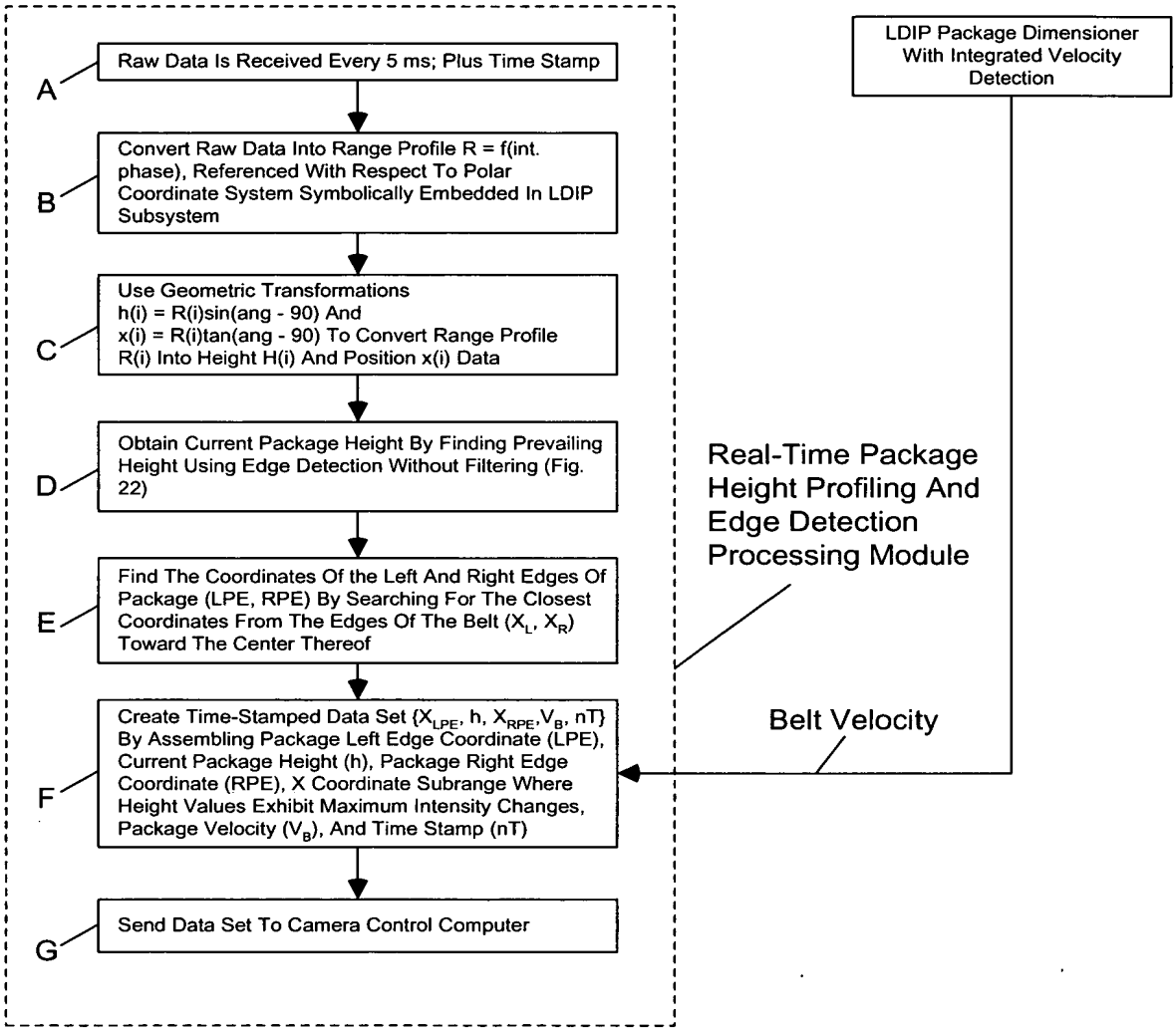
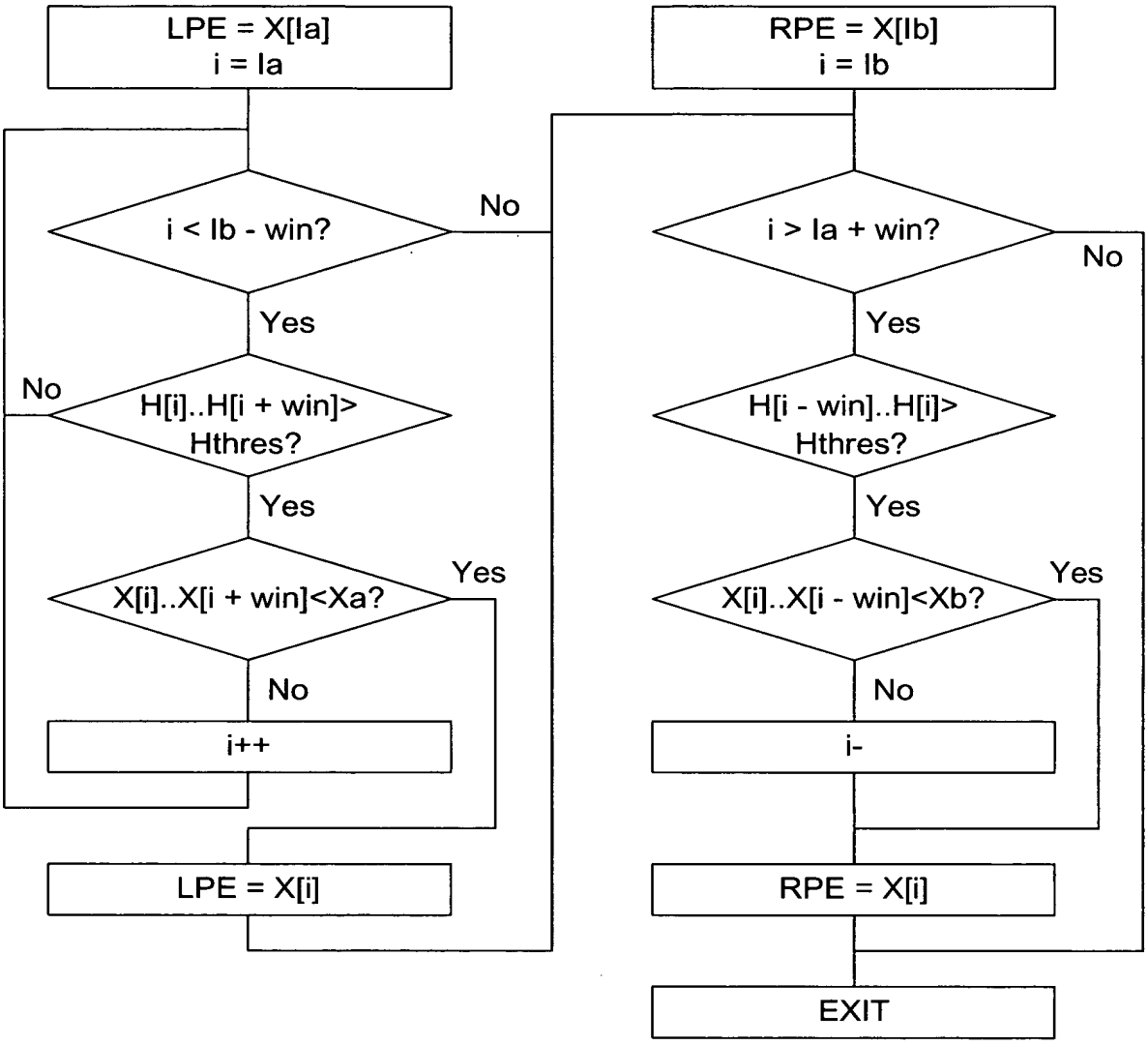


FIG. 21

REAL-TIME PACKAGE EDGE DETECTION METHOD



Xa = Location Of Belt Left Edge; Xb = Location Of Belt Right Edge
Ia = Belt Left Edge Pixel; Ib = Belt Right Edge Pixel
LPE = Left package Edge; RPE = Right Package Edge
H[] = Pixel Height Array; X[] = Pixel Location Array
win = Package detection Window

FIG. 22

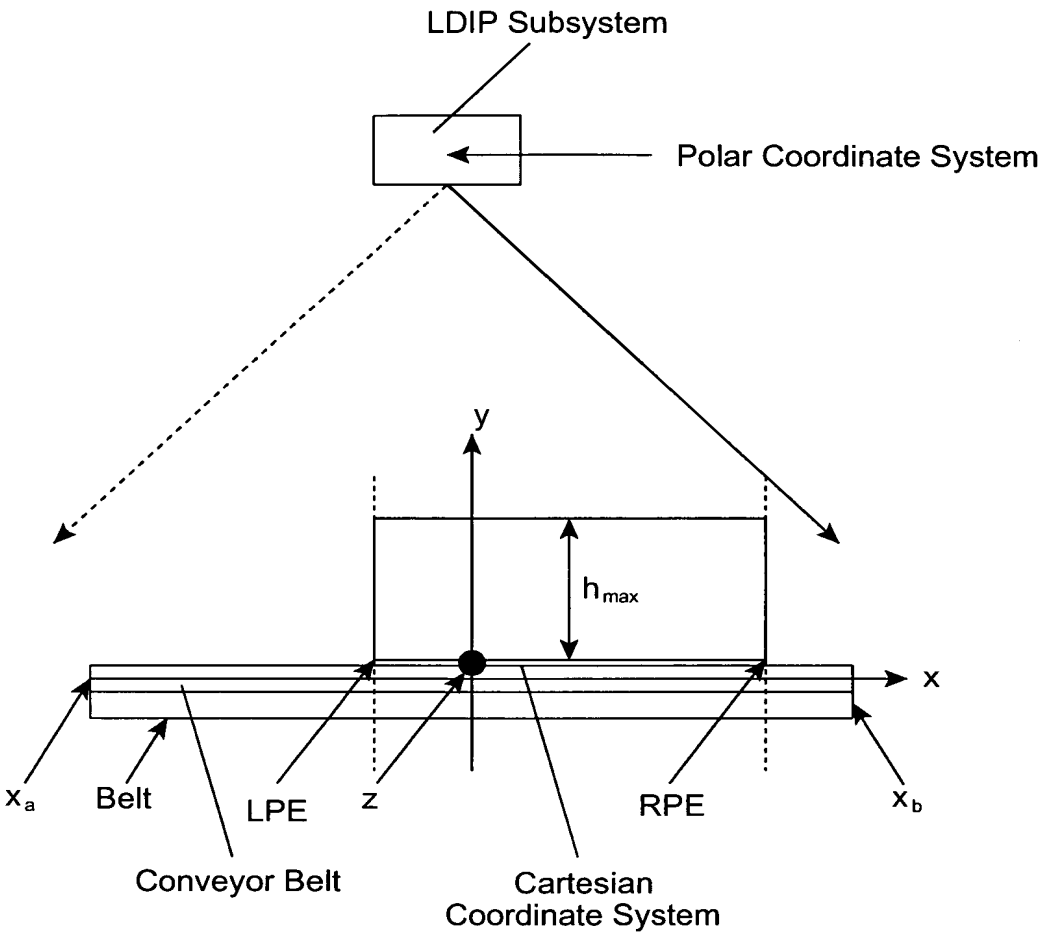

LDIP Subsystem
Polar Coordinate System
y
h_{max}
x
x_a
Belt
LPE
z
RPE
x_b
Conveyor Belt
Cartesian
Coordinate System

FIG. 23

CAMERA CONTROL PROCESS CARRIED OUT WITHIN THE CAMERA CONTROL SUBSYSTEM

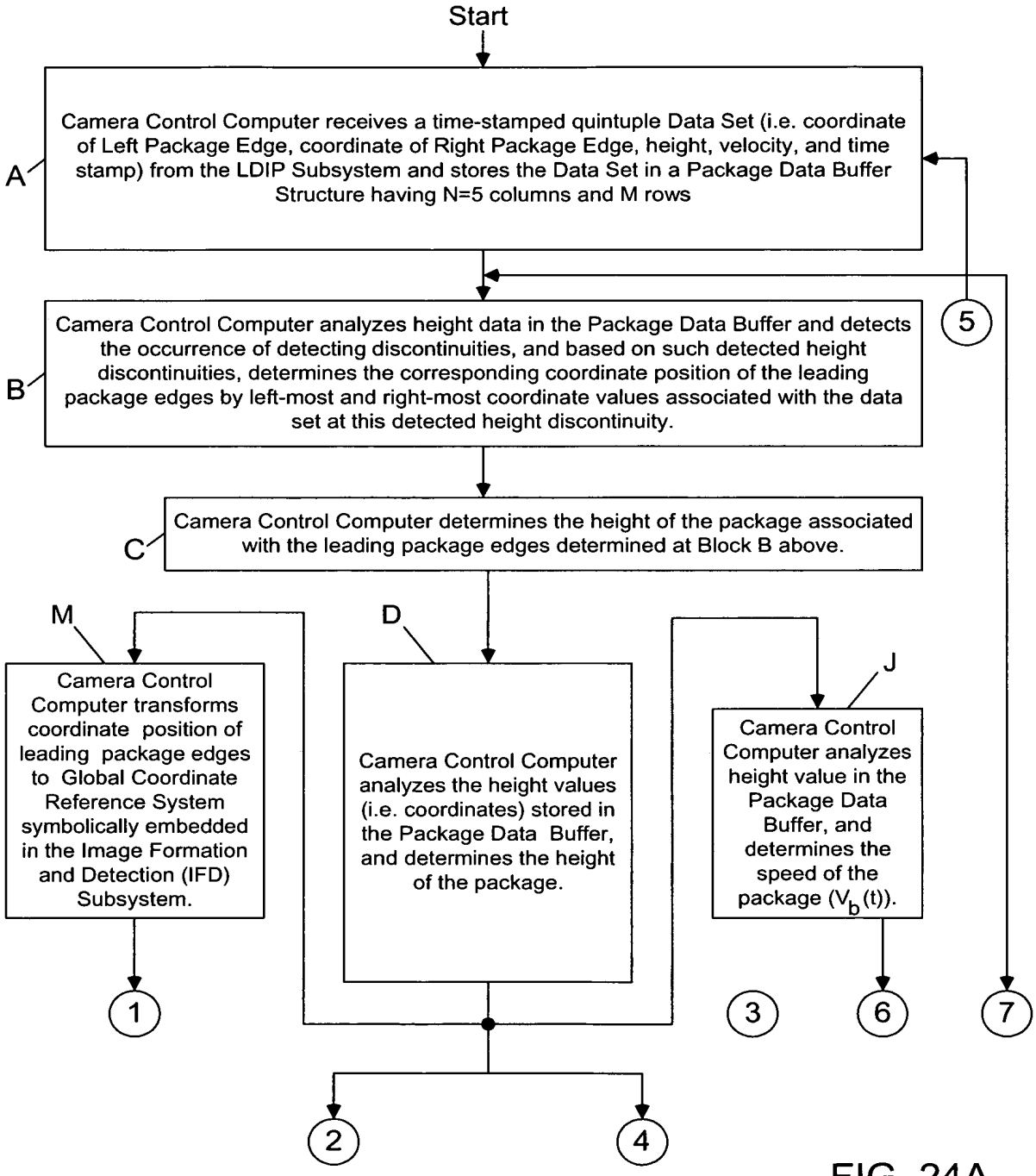


FIG. 24A

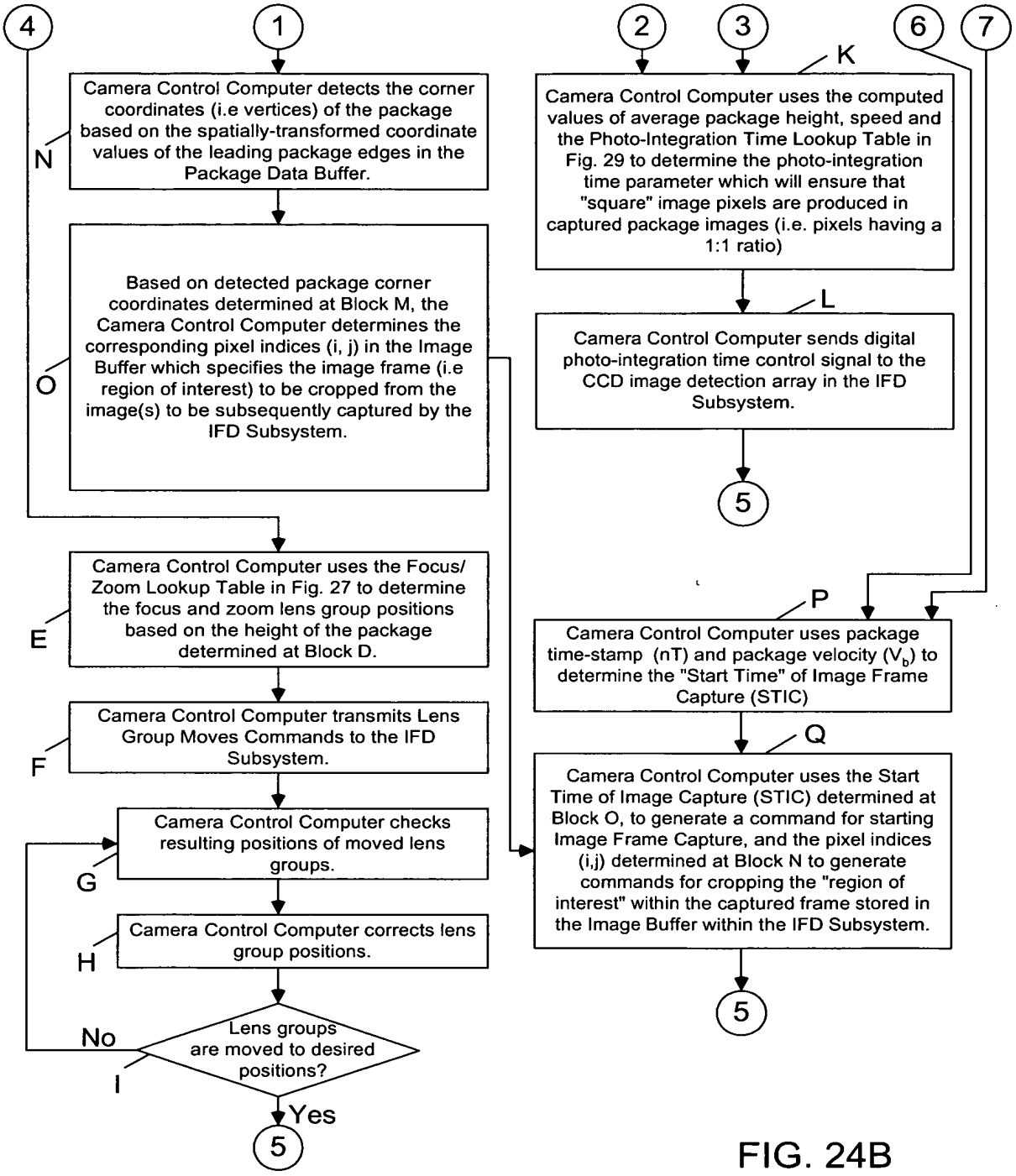

4
1
2
3
6
7
K
Camera Control Computer detects the corner coordinates (i.e vertices) of the package based on the spatially-transformed coordinate values of the leading package edges in the Package Data Buffer.
N
Camera Control Computer uses the computed values of average package height, speed and the Photo-Integration Time Lookup Table in Fig. 29 to determine the photo-integration time parameter which will ensure that "square" image pixels are produced in captured package images (i.e. pixels having a 1:1 ratio)
L
Camera Control Computer sends digital photo-integration time control signal to the CCD image detection array in the IFD Subsystem.
Based on detected package corner coordinates determined at Block M, the Camera Control Computer determines the corresponding pixel indices (i, j) in the Image Buffer which specifies the image frame (i.e region of interest) to be cropped from the image(s) to be subsequently captured by the IFD Subsystem.
O
5
Camera Control Computer uses the Focus/ Zoom Lookup Table in Fig. 27 to determine the focus and zoom lens group positions based on the height of the package determined at Block D.
E
P
Camera Control Computer uses package time-stamp (nT) and package velocity (V_b) to determine the "Start Time" of Image Frame Capture (STIC)
Q
Camera Control Computer transmits Lens Group Moves Commands to the IFD Subsystem.
F
Camera Control Computer uses the Start Time of Image Capture (STIC) determined at Block O, to generate a command for starting Image Frame Capture, and the pixel indices (i,j) determined at Block N to generate commands for cropping the "region of interest" within the captured frame stored in the Image Buffer within the IFD Subsystem.
Camera Control Computer checks resulting positions of moved lens groups.
G
Camera Control Computer corrects lens group positions.
H
5
No
Lens groups are moved to desired positions?
I
Yes
5

FIG. 24B

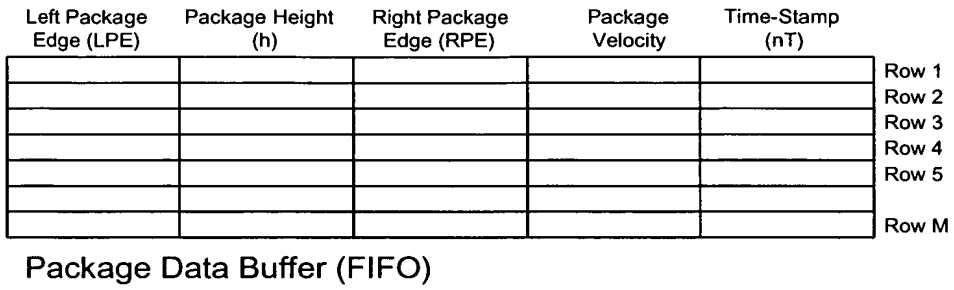

Left Package Edge (LPE)
Package Height (h)
Right Package Edge (RPE)
Package Velocity
Time-Stamp (nT)
Row 1
Row 2
Row 3
Row 4
Row 5
Row M
Package Data Buffer (FIFO)

FIG. 25

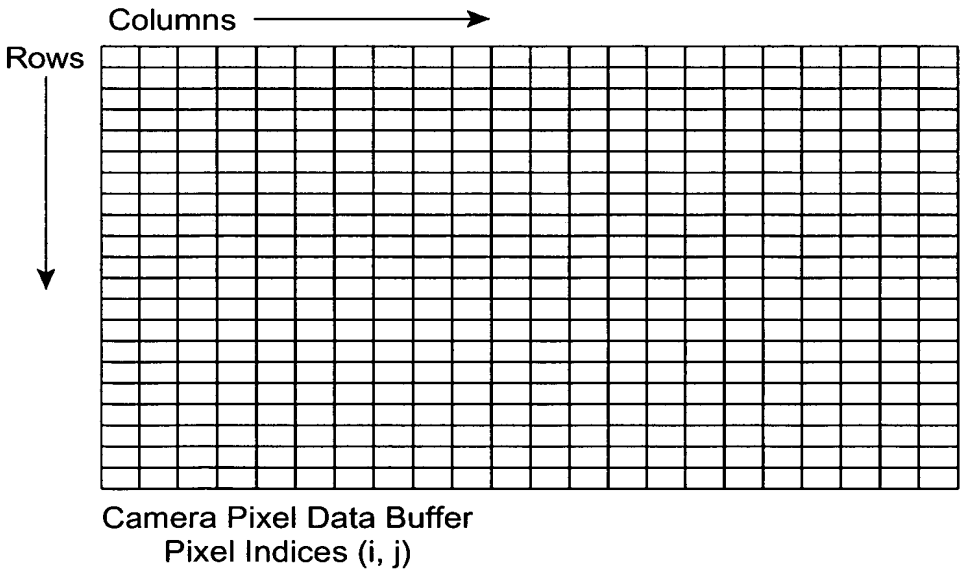

Columns
Rows
Camera Pixel Data Buffer
Pixel Indices (i, j)

FIG. 26

Zoom And Focus Lens Group Position
Look-Up Table

Distance From Camera H (mm)		Zoom Group Distance (mm) Y (Zoom)	Focus Group Distance (mm) Y (Focus)
(Use Interpolation Techniques For Working Distances Between Listed Points In Table)	1000	21.57489228	2.47E-05
	1100	19.38089696	10.99009783
	1200	17.10673434	20.65783177
	1300	14.77137314	29.10917002
	1400	12.39153565	36.47312595
	1500	9.979114358	42.87845436
	1600	7.540639114	48.44003358
	1700	5.078794775	53.25495831
	1800	2.595989366	57.40834303
	1900	0.099972739	60.98883615

FIG. 27

* Note: The focal distance and zoom (eff. focal length) of camera lens are coupled (inter-dependant) in this commercial embodiment.

Camera Has A Fixed Aperture F56

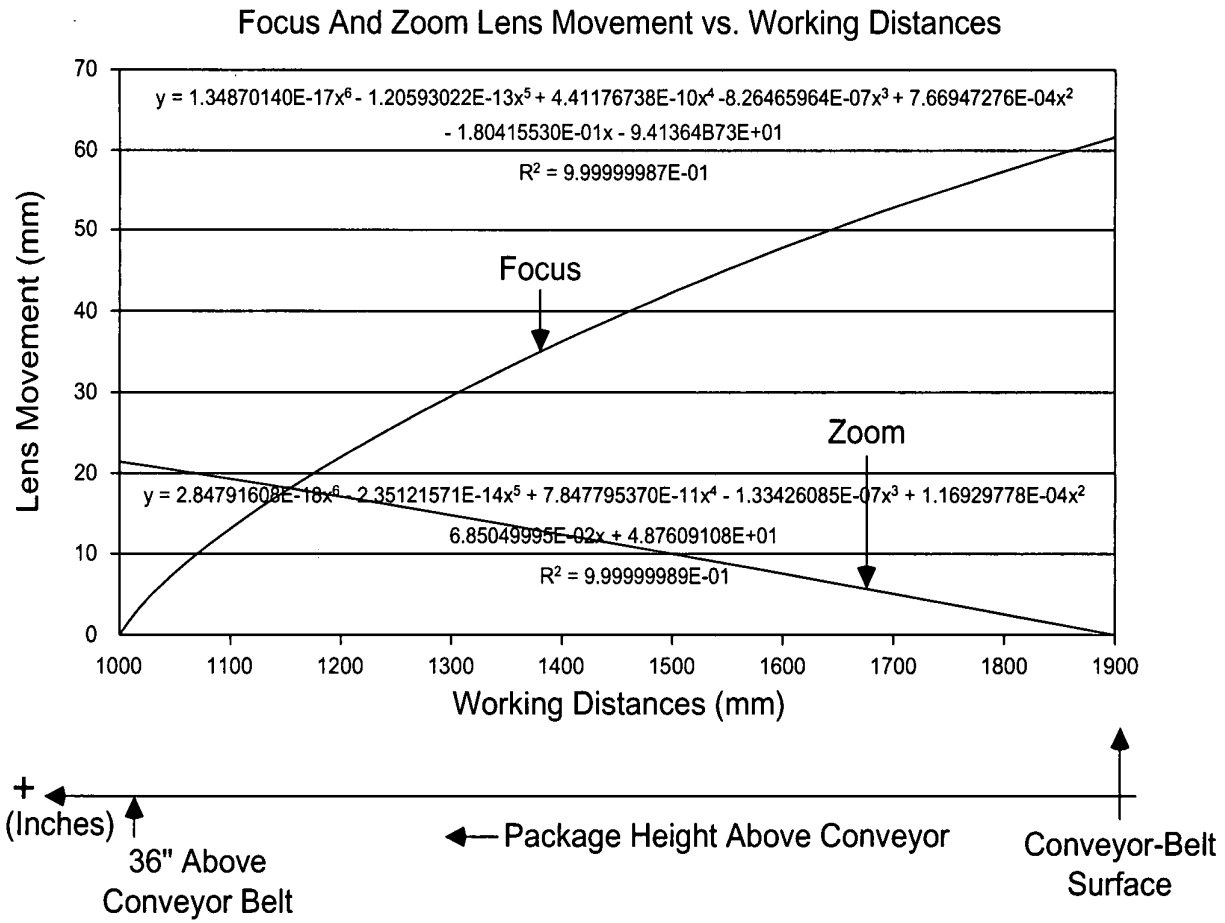


FIG. 28

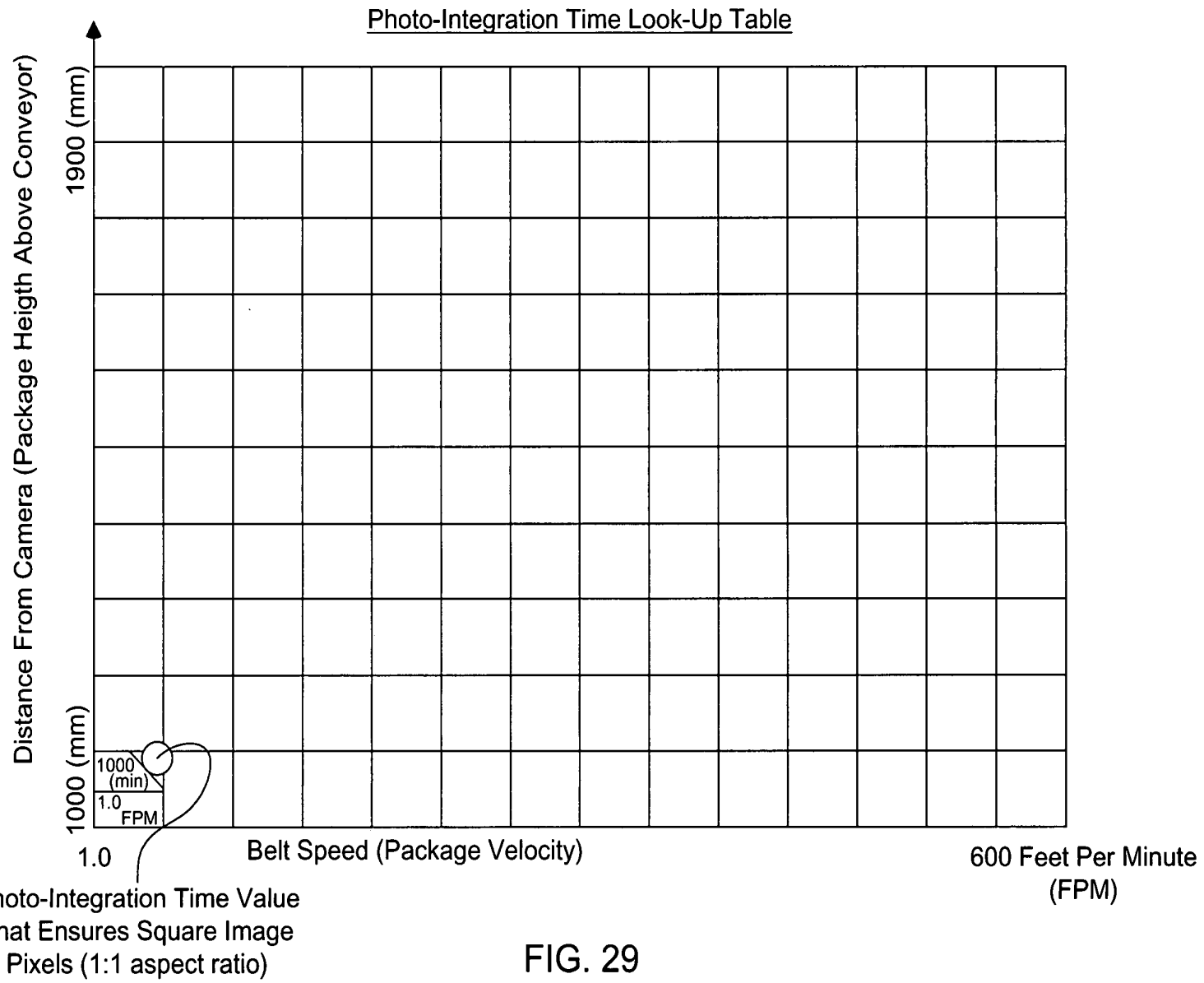


Photo-Integration Time Look-Up Table
Distance From Camera (Package Heigth Above Conveyor)
1900 (mm)
1000 (mm)
1000 (min)
1.0 FPM
1.0
Belt Speed (Package Velocity)
600 Feet Per Minute (FPM)
Photo-Integration Time Value That Ensures Square Image Pixels (1:1 aspect ratio)

FIG. 29

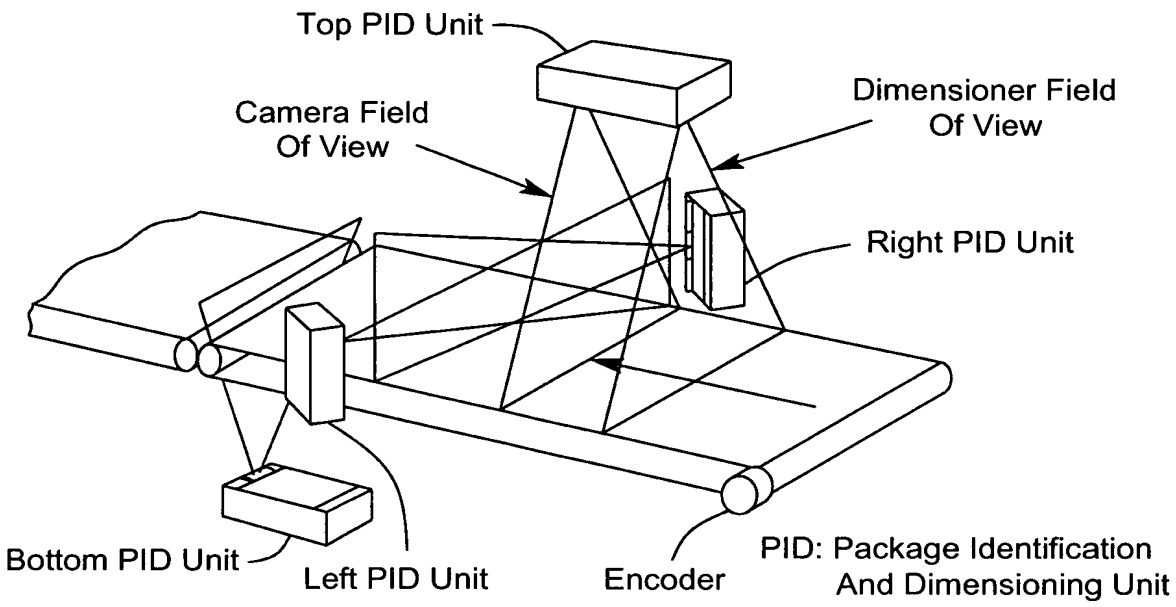

Top PID Unit
Camera Field
Of View
Dimensioner Field
Of View
Right PID Unit
Bottom PID Unit
Left PID Unit
Encoder
PID: Package Identification
And Dimensioning Unit

FIG. 30

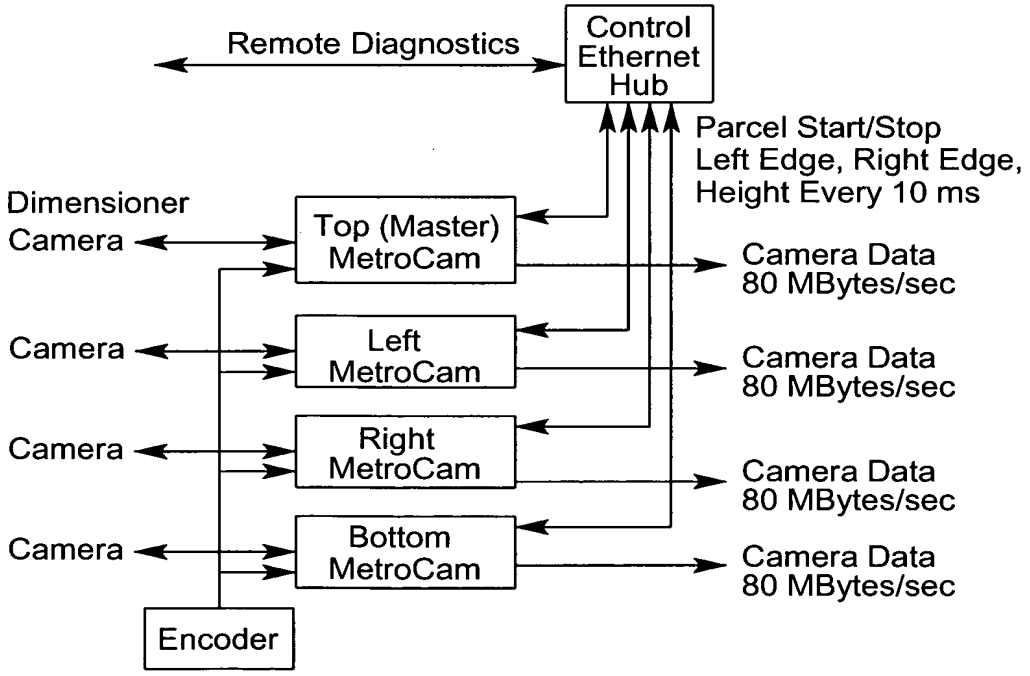

Remote Diagnostics
Control
Ethernet
Hub
Parcel Start/Stop
Left Edge, Right Edge,
Height Every 10 ms
Dimensioner
Camera
Top (Master)
MetroCam
Camera Data
80 MBytes/sec
Camera
Left
MetroCam
Camera Data
80 MBytes/sec
Camera
Right
MetroCam
Camera Data
80 MBytes/sec
Camera
Bottom
MetroCam
Camera Data
80 MBytes/sec
Encoder

FIG. 31

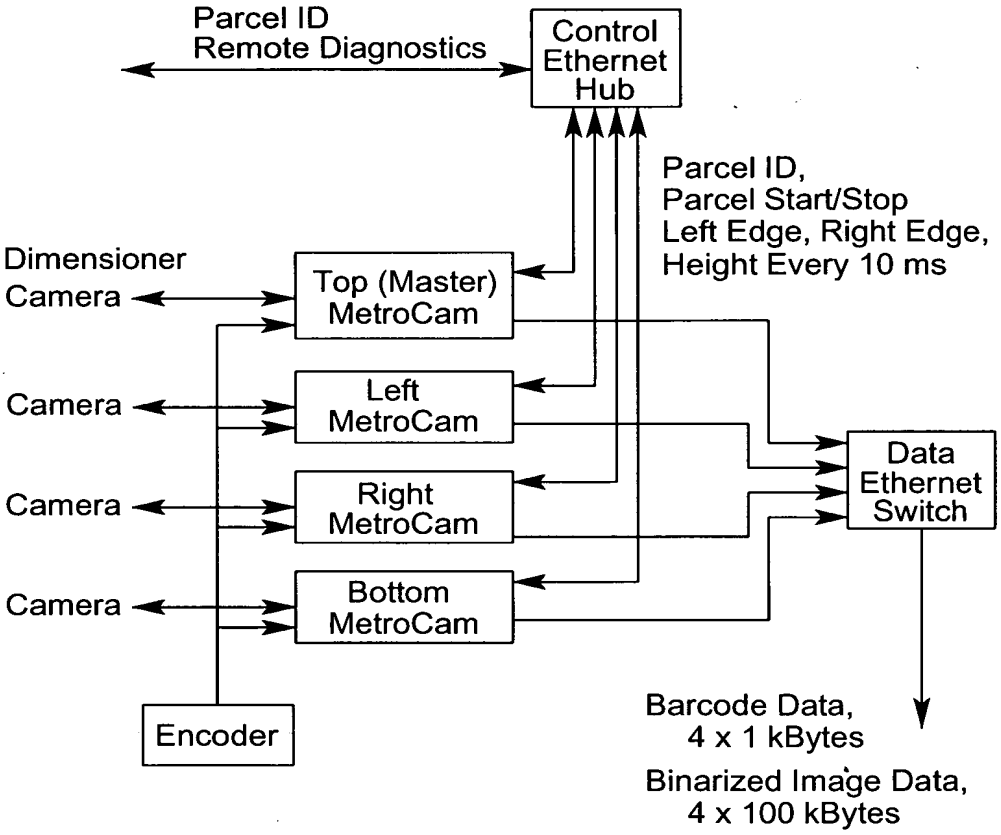

Parcel ID
Remote Diagnostics
Control
Ethernet
Hub
Parcel ID,
Parcel Start/Stop
Left Edge, Right Edge,
Height Every 10 ms
Dimensioner
Camera
Top (Master)
MetroCam
Camera
Left
MetroCam
Camera
Right
MetroCam
Camera
Bottom
MetroCam
Data
Ethernet
Switch
Encoder
Barcode Data,
4 x 1 kBytes
Binarized Image Data,
4 x 100 kBytes

FIG. 32